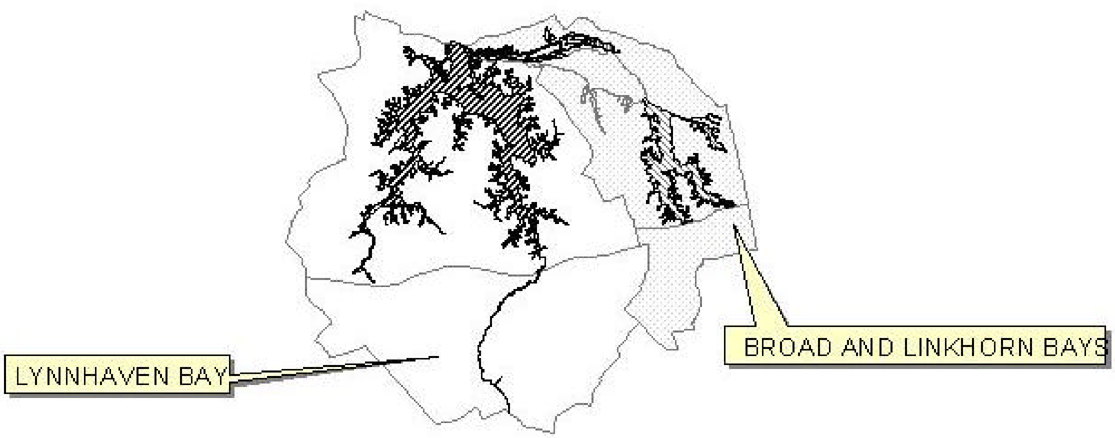
Lynnhaven Bay, Broad Bay and Linkhorn Bay Watersheds Total Maximum Daily Load (TMDL) Report for Shellfish Areas Listed Due to Bacteria Contamination



Virginia Department of Environmental Quality

March 2004

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1.0 Introduction

This document details the development of two bacteria TMDLs; one for the segment comprising all of the Lynnhaven Bay and its tributaries, including Long Creek; and one segment comprising the Mill Dam Creek and Dell Cove portions of Broad Bay and all of Linkhorn Bay. These watersheds are completely within the City of Virginia Beach, Virginia and are handled on a watershed basis in this report. All segments are listed as impaired on Virginia's 303(d) Total Maximum Daily Load Priority List. The TMDL is one step in a multi-step process that include a very high level of public participation in order to facilitate the correction of water quality issues which can affect public health and the health of aquatic life.

1.1 Listing of Water Bodies Under the Clean Water Act

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies which are exceeding water quality standards. TMDLs represent the total pollutant loading that a water body can receive without violating water quality standards. Water quality standards are numeric or narrative limits on pollutants that are developed to ensure the protection of human health and or aquatic life. The TMDL process establishes the allowable loading of pollutants for a water body based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (EPA, 1991).

Waters that are determined to be impaired can be free-flowing streams, lakes and tidal waters, anywhere in Virginia. Bacteria are the most common cause for the impairments. In Virginia, we have identified a need to develop 644 TMDLs by 2010. Of these approximately 230+ are shellfish water closures due to excessive levels of fecal coliform bacteria. Among these shellfish areas, two segments within the Lynnhaven, Broad and Linkhorn Bays have been regulated pursuant to Title 28.2 Chapter 8, sections 228.2-803, 228.2-808, 32.1-20 and 9-6.14:4.1 B16 of the Code of Virginia by the Virginia Department of Health, Division of Shellfish Sanitation (VDH-DSS). Notice and Description of Shellfish Condemnation Area 25, Lynnhaven River, Broad Creek and Linkhorn Bay describes and delineates the restricted harvest areas that are listed because water quality monitoring data show excessive levels of bacteria in these waters. The waters also were classified as impaired on the state's 303(d) list of impaired waters and require a TMDL.

1.2 Overview of the TMDL Development Process

The TMDL study for these waters is the first part of a three-step process aimed at restoring water quality. This study is designed to determine how much of pollutant input needs to be reduced in order to achieve water quality standards. The second step in the process is the development of an implementation plan that identifies which specific control measures are necessary to achieve those reductions, their timing for implementation and at what cost. The implementation plan will also outline potential funding sources. The third step will be the actual implementation process. Implementation will typically occur in stages that allow a review of progress in reducing pollutant input and to make any identified changes to pollutant control measures.

Agencies of the Commonwealth, including the Department of Environmental Quality (DEQ), the VDH-DSS and the Department of Conservation and Recreation (DCR) have worked together with state universities, the U.S. Geological Survey and the U.S. Environmental Protection Agency to develop an appropriate methodology for TMDLs in impaired shellfish waters. This method utilizes bacteria source tracking (BST) data to determine the potential sources of fecal coliform in the water. It has been shown that BST data can provide information to assist in the identification and targeting sources of bacterial pollution. In addition to the BST data, the TMDL will be developed using VDH-DSS monthly monitoring and sanitary shoreline surveys. The results of this study as applied to the Lynnhaven, Broad and Linkhorn Bays is described in section 5.0. Finally, to assist with the analysis and development of the TMDLs for these rivers and other impaired water bodies in the City of Virginia Beach, the Department of Environmental Quality has contracted with the Virginia Institute of Marine Science for further technical assistance.

The TMDL development process also must account for seasonal and annual variations in precipitation, flow, land-use, and pollutant contributions. Such an approach helps to ensure that TMDLs, when implemented, do not result in violations under a wide variety of scenarios that affect bacteria loading.

1.3 Classification of Virginia's Shellfish Growing Areas

The VDH-DSS is responsible for classifying and ensuring the health for human consumption of Virginia's shellfish resources. The VDH-DSS collects monthly samples at over 2,000 stations in the shellfish growing areas of Virginia. Every 6 months, the Department determines if the data show that the water quality standard is met. If the water quality standards are exceeded, the shellfish area is closed for the harvest of shellfish that go directly to market. These areas that exceed the water quality standard and are closed for the direct marketing of shellfish are eligible for harvest of shellfish under permit from the Virginia Marine Resources Commission and VDH-DSS. The permit establishes controls that in part require shellfish be allowed to depurate for 15 days in clean growing areas or specially designed and licensed on shore facilities. DSS follows the requirements of the National Shellfish Sanitation Program (NSSP), which is regulated by the U.S. Food and Drug Administration. The NSSP classification specifies the use of a shoreline survey completed by DSS as its primary tool for classifying shellfish growing waters. Fecal coliform concentrations in water samples collected in the immediate vicinity of the shellfish beds function to verify the findings of the shoreline survey, and to define the border between approved and condemned (unapproved) waters.

DSS develops the shoreline survey to locate as many sources of pollution as possible within the watersheds of shellfish growing areas. This is accomplished through a property-by-property inspection of the onsite sanitary waste disposal facilities on un-sewered sections of watersheds, and investigations of other sources of pollution such as wastewater treatment plants (WTP), marinas, livestock operations, landfills, etc. The information is compiled into a written report with a map showing the location of the sources of real or potential pollution found, and sends it to the various state agencies that are responsible for regulating these concerns and the city or county.

Once an onsite problem is identified local health departments (LHDs), or other state or local agencies may play a major role in the process of correcting the onsite sanitary waste disposal problems.

Most of the DSS effort is focused on locating fecal contamination, and in this manner facilitating the prevention of significant amounts of human pathogens from getting into shellfish waters.

In addition to the shoreline survey, the NSSP requires that DSS collect seawater samples in the growing areas as part of the classification procedure. States must use the most recent 30 samples, collected randomly with respect to weather (scheduled one month in advance), to assess a sampling location. The two part standard for fecal coliforms in waters for direct shellfish harvest to market is a geometric mean no greater than 14 MPN fecal coliforms/100 ml and an estimated 90^{th} percentile no greater than 49 MPN/100ml. Exceeding either number requires closure of that station. In Virginia, most of the high fecal coliform counts are due either to runoff resulting from development, agriculture and livestock operations, or from wildlife.

2.0 Applicable Water Quality Standard

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term *"water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."*
As stated above, Virginia water quality standards consist of a designated use or uses and a water quality criteria. These two parts of the applicable water quality standard are presented in the sections that follow.

2.1 Designated Uses
According to Virginia Water Quality Standards (9 VAC 25-260-10A), *"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

2.2 Applicable Water Quality Criteria

For a shellfish supporting water body to be in compliance with Virginia's bacteria standards for the production of edible and marketable natural resources use, VADEQ specifies the following criteria (9 VAC 25-260-160): "*In all open ocean or estuarine waters capable of propagating shellfish or in specific areas where public or leased private shellfish beds are present, and including those waters on which condemnation or restriction classifications are established by the State Department of Health the following criteria for fecal coliform bacteria shall apply; The geometric mean fecal coliform value for a sampling station shall not exceed an MPN (most probable number) of 14 per 100 milliliters. The 90^{th} percentile shall not exceed an MPN of 43 for a 5 tube, 3 dilution test or 49 for a 3 tube, 3 dilution test"*

3.0 Watershed and Water Quality Characterization

The Lynnhaven, Broad and Linkhorn Bay's water quality problems are the result of the interactions between the existing physical environment and anthropogenically (i.e. human) induced alterations to the watershed. The examination of these characteristic is critical to understanding the potential resolution of these impairments.

3.1 Physical Environment

The Lynnhaven, Broad and Linkhorn Bays are located entirely within the City of Virginia Beach in southeastern Virginia at the southern shore of the mouth of the Chesapeake Bay, near Cape Henry. It occupies a landscape position along the southern shore of the mouth of the Chesapeake Bay between Cape Henry and the Chesapeake Bay Bridge Tunnel in Virginia's Coastal Plain Physiographic Province and the Coastal Lowland sub province. The Coastal Lowland sub-province is characterized by flat, low relief regions along the major rivers and Chesapeake Bay. Elevations range from 0' to 60' above mean sea level. The Virginia Coastal plain is underlain by deep tertiary and cretaceous formations of marine and deltaic sands and clay deposited some 146 million years ago, overlain by Yorktown and Eastover formations of marine sand and clay of more recent origin, this is topped by quaternary formations that are comprised of silts, sands and clays of principally fluvial and estuarine origin. The foregoing layers rest atop the deep igneous and metamorphic rock base formation. The Lynnhaven, Broad and Linkhorn Bay watershed drains north to the Chesapeake Bay and is subject to the ebb and flow of the tide. The Lynnhaven Bay flows north from its headwaters bordering State Interstate Route 264 (SR 44) to the south, SR 279 to the east and SR 225 and 190 to the west. Broad Bay and Linkhorn Bay~~s~~ lie directly east of SR 279. Broad Bay is bordered on the northeast by First Landing State Park, and to the east by US 60. This tributary enters Lynnhaven Bay at its confluence with the Chesapeake Bay.

The drainage area of the Lynnhaven, Broad and Linkhorn Bay watershed is approximately 40,683 acres, or 64 square miles. The nearest climate station is located in at Cape Henry in Virginia Beach, Virginia approximately 2 miles east of the study area. The average annual rainfall as recorded at Cape Henry is 41.32 inches. Table 3-1 presented below provides a monthly average summary of climate data for the Cape Henry, Virginia weather station (SRCC 2002).

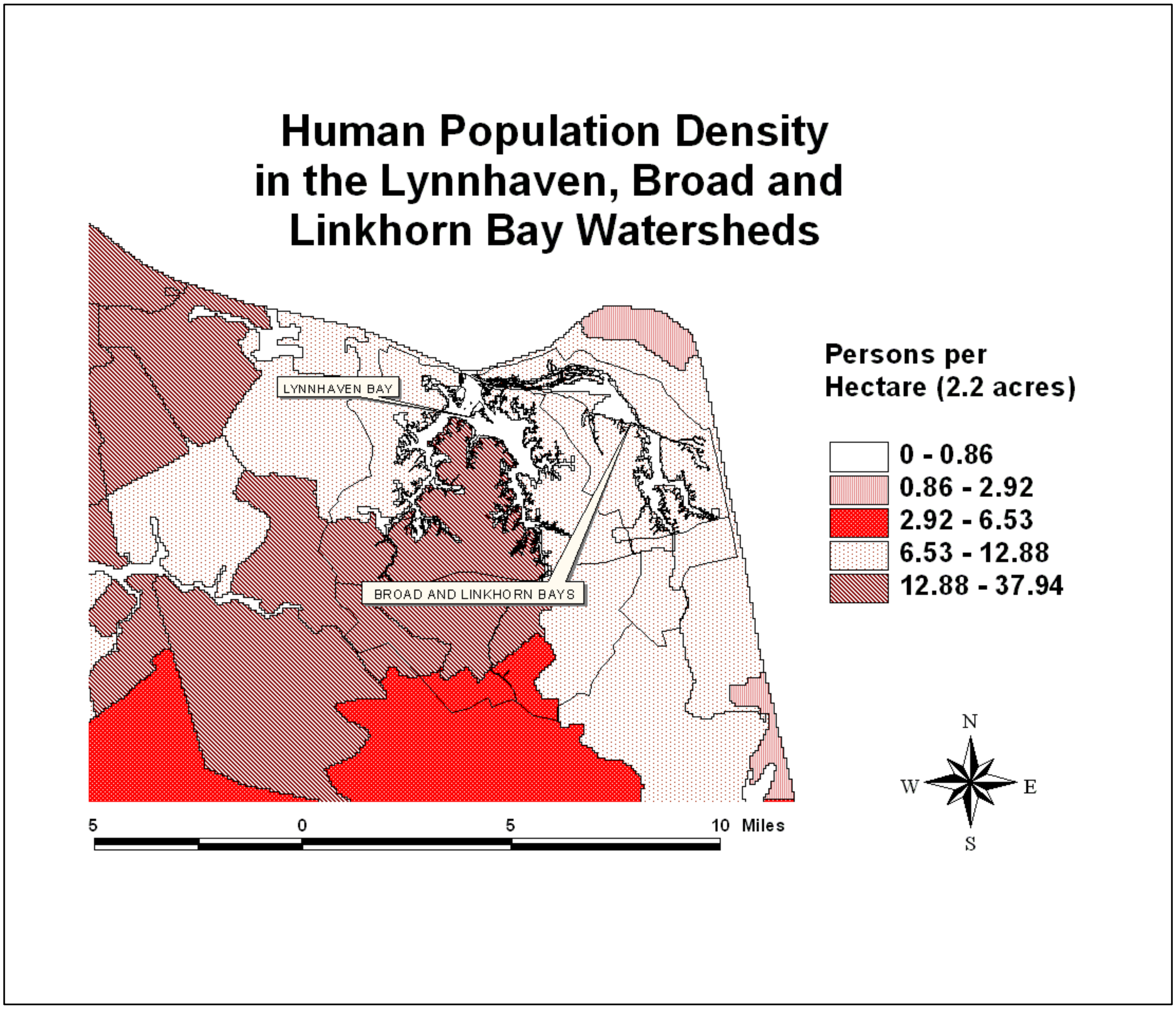
Table 3-1. Climate Data for Cape Henry WB City, Virginia (441362)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max Temp	48.3	49.1	55.1	65.3	72.7	80.5	85.0	83.7	77.8	68.0	59.6	50.4	66.4
Avg. min. Temp	35.0	35.0	40.3	49.4	58.0	66.5	71.2	70.9	66.6	56.8	46.4	37.0	52.8
Avg. Total Precipitation	2.81	3.17	3.04	2.67	3.26	3.84	4.65	5.68	3.54	3.04	2.54	30.5	41.32
Avg. Total Snowfall (in.)	2.1	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	4.8

** Source: Southeast Regional Climate Center, sercc@dnr.state.sc.us*

The area comprising the Lynnhaven, Broad and Linkhorn Bays can be characterized as highly urbanized and densely populated. Population distribution expressed as density of individuals per unit area (number of individuals per hectare) is shown if Figure 3-1.

Figure 3-1



Land use in the Lynnhaven, Broad and Linkhorn Bay watershed is highly homogeneous consisting predominantly of single family homes and similar developments. The watershed can therefore be described as a dense suburban/urban mixture. Undeveloped land comprises less than 25% of the total watershed as forest, wetland, urban grassland, or water. Approximately 75% of the Lynnhaven, Broad and Linkhorn Bay watershed is characterized as developed for residential, streets, commercial and office space, or for military use. Land use area by category is shown in Table 3-2 and Figure 3-2.

Table 3-2. Land use in the Lynnhaven , Broad and Linkhorn Bay watershed

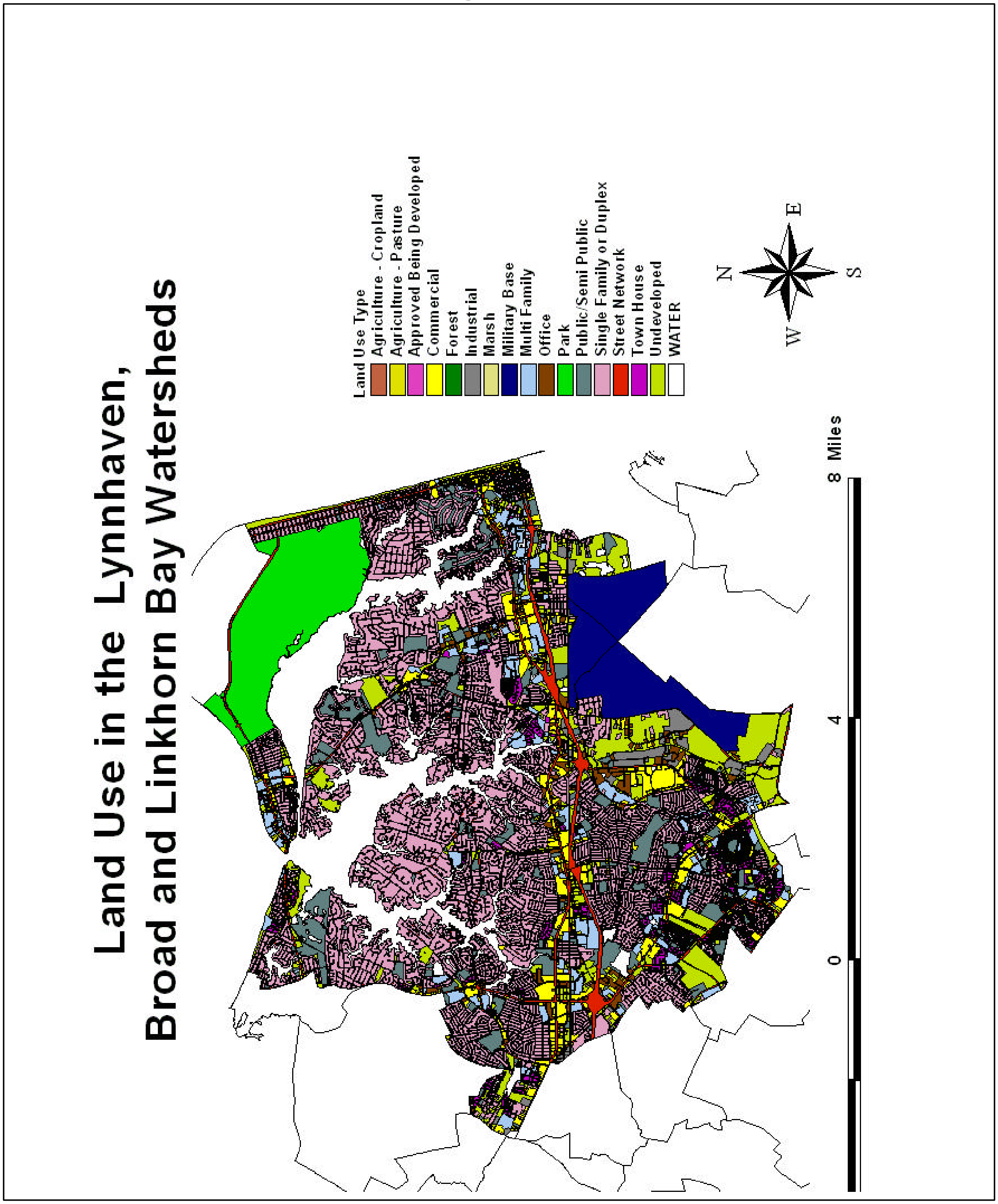
Land Use Category	Area (acres)	Area (%)
Single Family/Duplex	15078	37%
Town House	768	2%
Multi-family	1551	4%
Commercial	1806	4%
Office	652	2%
Industrial	457	1%
Military	2393	6%
Streets	5178	13%
Public/Semi-public	2662	7%
Park	2876	7%
Agriculture-cropland	1717	4%
Agriculture-pasture	248	1%
Marsh/wetland	1711	4%
Approved f/development	6	0%
Undeveloped	3580	9%
Total Area	40683	100%

Source: Virginia Beach Department of Public Works

3.2 Water Quality Impairment by Condemnation Area

One segment in each of the Lynnhaven Bay, Broad and Linkhorn Bays were listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 1998) due to violations of the State's water quality standard for fecal coliform bacteria in shellfish supporting waters. VDH-DSS, Notice and Description of Shellfish Condemnation Number 25, Lynnhaven River, Broad and Linkhorn Bays, lists and describes the condemnation areas in these watersheds and their tributaries. The narrative portion of document is included in Appendix A. Maps of the shellfish condemnation areas and their associated water quality stations are available from the VDH-DSS. A generalized map of the areas affected by the condemnation notice is shown in Figure 3-3. Figure 3-4 provides a generalized overview of the results of the DSS shoreline survey in the Lynnhaven, Broad ands Linkhorn Bay watersheds.

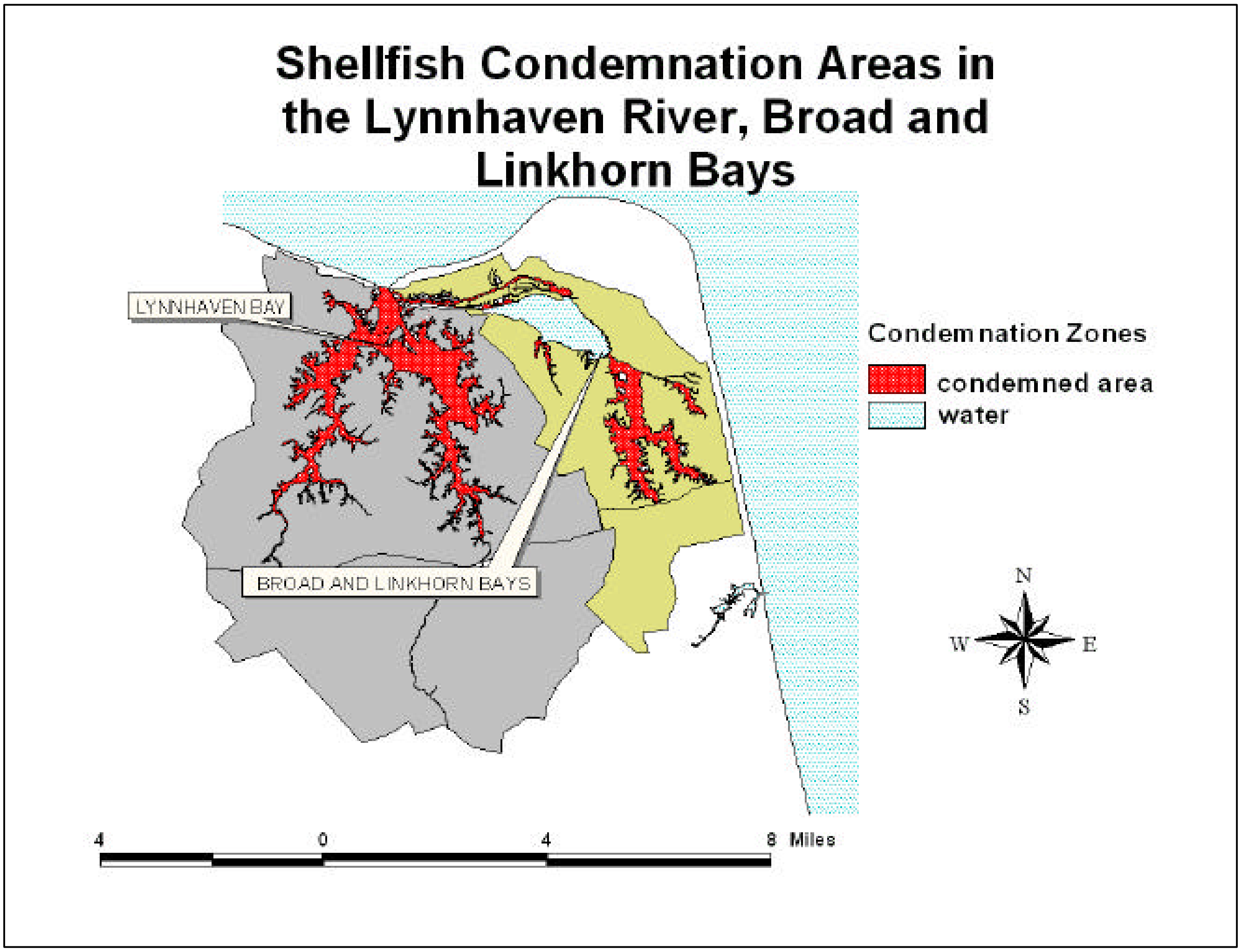
Figure 3-2



Land Use in the Lynnhaven,
Broad and Linkhorn Bay Watersheds
Land Use Type
Agriculture - Cropland
Agriculture - Pasture
Approved Being Developed
Commercial
Forest
Industrial
Marsh
Military Base
Multi Family
Office
Park
Public/Semi Public
Single Family or Duplex
Street Network
Town House
Undeveloped
WATER
N
S
E
W
0
4
8 Miles

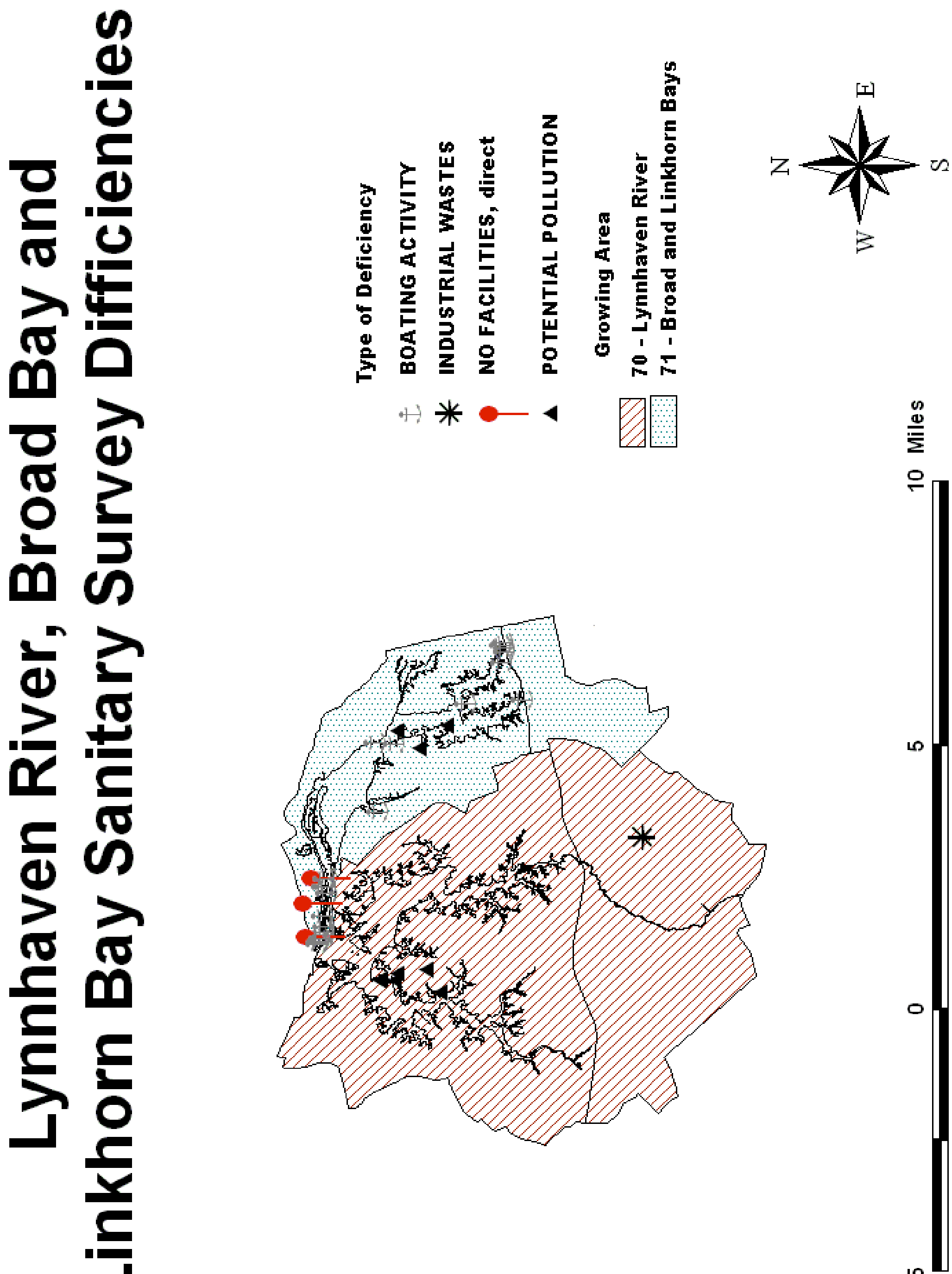
The Lynnhaven Bay water quality monitoring network consists of 19 monitoring stations. Broad and Linkhorn Bays have an additional 21 stations. These stations are monitored by the VDH-DSS for fecal coliform bacteria. Based upon the results of this monitoring the status of the closure areas are re-evaluated at a minimum annually, but normally semi-annually. The network of water quality monitoring stations for the Lynnhaven River estuary is shown in Figure 3-5. Several of these stations represent the downstream limits of the shellfish closure area due to bacteria others represent a transect from near shore to mid reach to far shore.

FIGURE 3-3



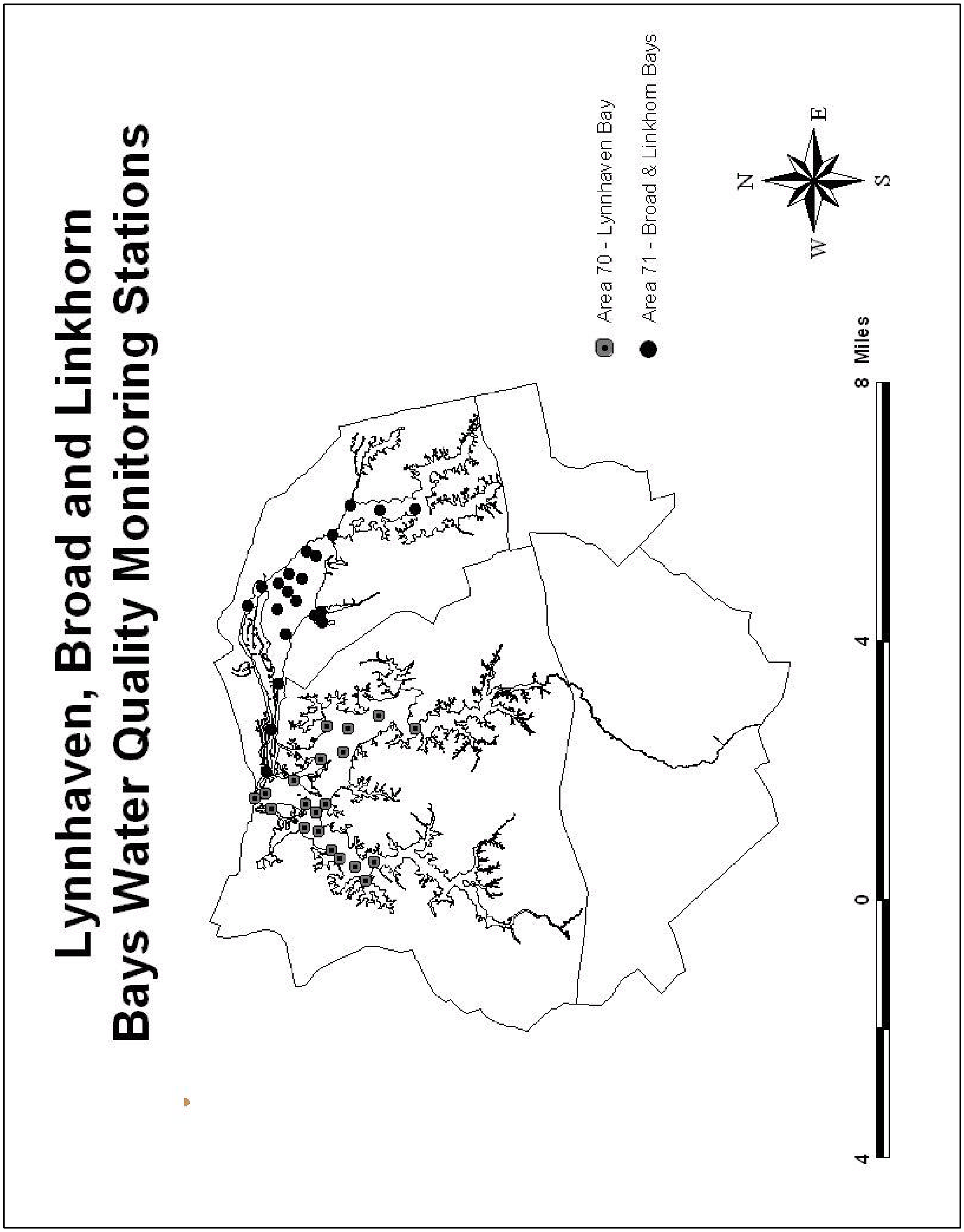
A subset of 10 stations was also selected for a special study to facilitate the development of TMDLs for these segments. This TMDL study examined bacterial sources at these stations on a monthly basis from September of 2001 through August of 2002. A summary of water quality for the 30 months preceding the TMDL study and data is shown in Table 3-3. Figure 3-6 shows the location of the TMDL study stations.

Figure 3-4



Lynnhaven River, Broad Bay and
Linkhorn Bay Sanitary Survey Difficiencies
Type of Deficiency
BOATING ACTIVITY
INDUSTRIAL WASTES
NO FACILITIES, direct
POTENTIAL POLLUTION
Growing Area
70 - Lynnhaven River
71 - Broad and Linkhorn Bays
N
E
S
W
5
0
5
10 Miles

Figure 3-5



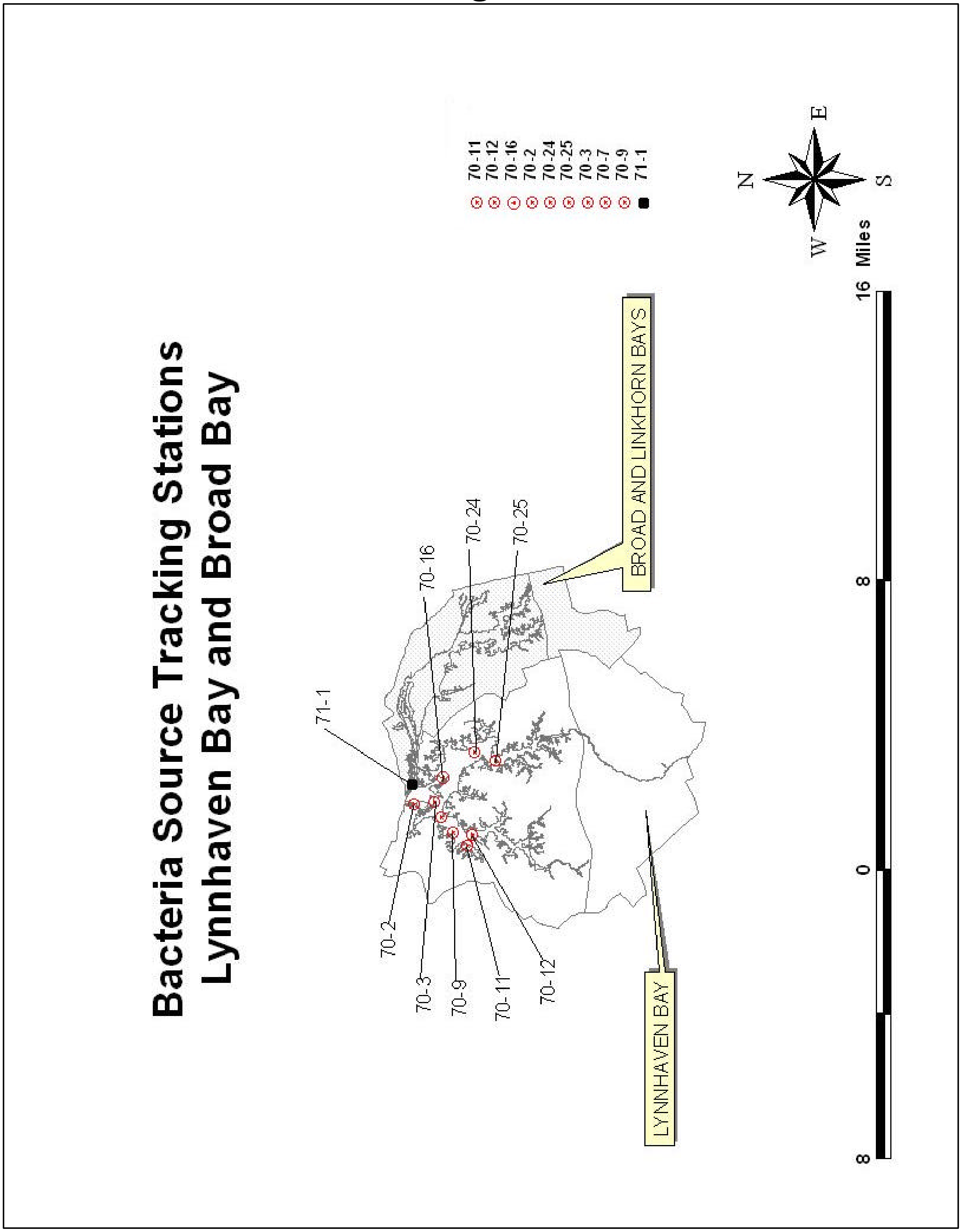
Lynnhaven, Broad and Linkhorn
Bays Water Quality Monitoring Stations
Area 70 - Lynnhaven Bay
Area 71 - Broad & Linkhorn Bays
N
E
S
W
4
0
4
8 Miles

Table 3-3 Lynnhaven, Broad and Linkhorn Bay Bacterial Water Quality Data Summary January 2001 to February 2003.

Station	90th Percentile Preceeding 30 Months	Water Quality Standard	Station Meets Standard?	Geometric Mean Preceding 30 months	Geometric Mean Standard	Station Meets Standard ?	Current Condem-nation
Lynnhaven		49			14		
25A-1	68.4		No	11.4		Yes	Yes
25A-2 *	111.7		No	16.8		No	Yes
25A-2Z	103.0		No	13.6		Yes	Yes
25A-3 *	259.0		No	27.2		No	Yes
25A4	190.1		No	24.7		No	Yes
25A4_3	258.0		No	31.6		No	Yes
25A-4_9	164.1		No	14.7		Yes	Yes
25A-5	143.3		No	19.2		No	Yes
25A-7*	209.7		No	21.0		No	Yes
25A-8	332.7		No	27.1		No	Yes
25A-9*	306.8		No	30.5		No	Yes
25A-10*	368.0		No	30.2		No	Yes
25A-11*	182.9		No	27.1		No	Yes
25A-12*	569.1		No	41.7		No	Yes
25A-15	116.6		No	14.5		Yes	Yes
25A-16*	195.1		No	18.7		No	Yes
25A-17	230.0		No	20.4		No	yes
25A-18	265.7		No	20.2		No	yes
25A-24*	445.0		No	36.6		No	Yes
25A-25*	760.7		No	52.6		No	Yes
Average	**264.0**			**25.0**			
Broad Bay and Linkhorn Bay Stations							
25B-1*	54.8		No	10.2		Yes	Yes
25B-1_6	51.9		No	10.5		Yes	Yes
25B-2	52.7		No	9.6		Yes	Yes
25B-3	66.1		No	10.2		Yes	Yes
25B-3Z	37.2		Yes	7.9		Yes	No
25B-4	62.4		No	8.0		Yes	Yes
25B-4A	209.4		No	22.0		No	Yes
25B-4B	443.9		No	30.9		No	Yes
25B-4C	287.0		No	24.3		No	Yes
25B-4U	187.2		No	10.2		Yes	Yes
25B-4V	23.8		Yes	5.8		Yes	No
25B-4W	32.7		Yes	7.4		Yes	No
25B-4X	13.4		Yes	4.0		Yes	No
25B-4Y	61.1		No	12.3		Yes	Yes
25B-4Z	34.4		Yes	8.6		Yes	No
25B-5	44.7		Yes	7.8		Yes	No
25B-5Z	29.1		Yes	5.7		Yes	No
25B-6	46.3		Yes	7.6		Yes	No
25B-7	59.9		No	8.6		Yes	Yes
25B-8	36.7		Yes	7.5		Yes	No
25B-9	72.2		No	9.8		Yes	Yes
Average	**90.17**			**10.9**			

*** Bacterial Source Tracking Stations**
Note: Values in Red Exceed Criteria

Figure 3-6


Bacteria Source Tracking Stations
Lynnhaven Bay and Broad Bay
71-1
70-16
70-24
70-25
70-2
70-3
70-9
70-11
70-12
BROAD AND LINKHORN BAYS
LYNNHAVEN BAY
70-11
70-12
70-16
70-2
70-24
70-25
70-3
70-7
70-9
71-1
N
E
S
W
8
0
8
16
Miles

The data for the BST special study areas in Lynnhaven Bay for the last 30 monthly sampling events which covers the period from January 2001 through February 2002 are graphically represented in Figure 3-6. These data show that the stations representing the condemnation areas that are the subject of this TMDL report, do not meet the established 90th Percentile standard of 49 MPN/100ml, or the geometric mean standard of 14 MPN/100ml. The one BST station representing the Broad and Linkhorn Bays, station 24B-1 is not graphed but has a geometric mean value of 10.2 MPN/100 ml and a 90th percentile geometric mean value of 54.8 MPN/100ml. This station does not meet the standard for the 90th percentile geometric mean of the last 30 sampling events. The data make it evident that the controlling condition for the bacterial levels is at the 90th percentile for all of the shellfish condemnation TMDLs in the Lynnhaven Bay watershed. It is expected that efforts undertaken to address this standard in the watershed would also ensure that the geometric mean standard is met.

Figure 3-7

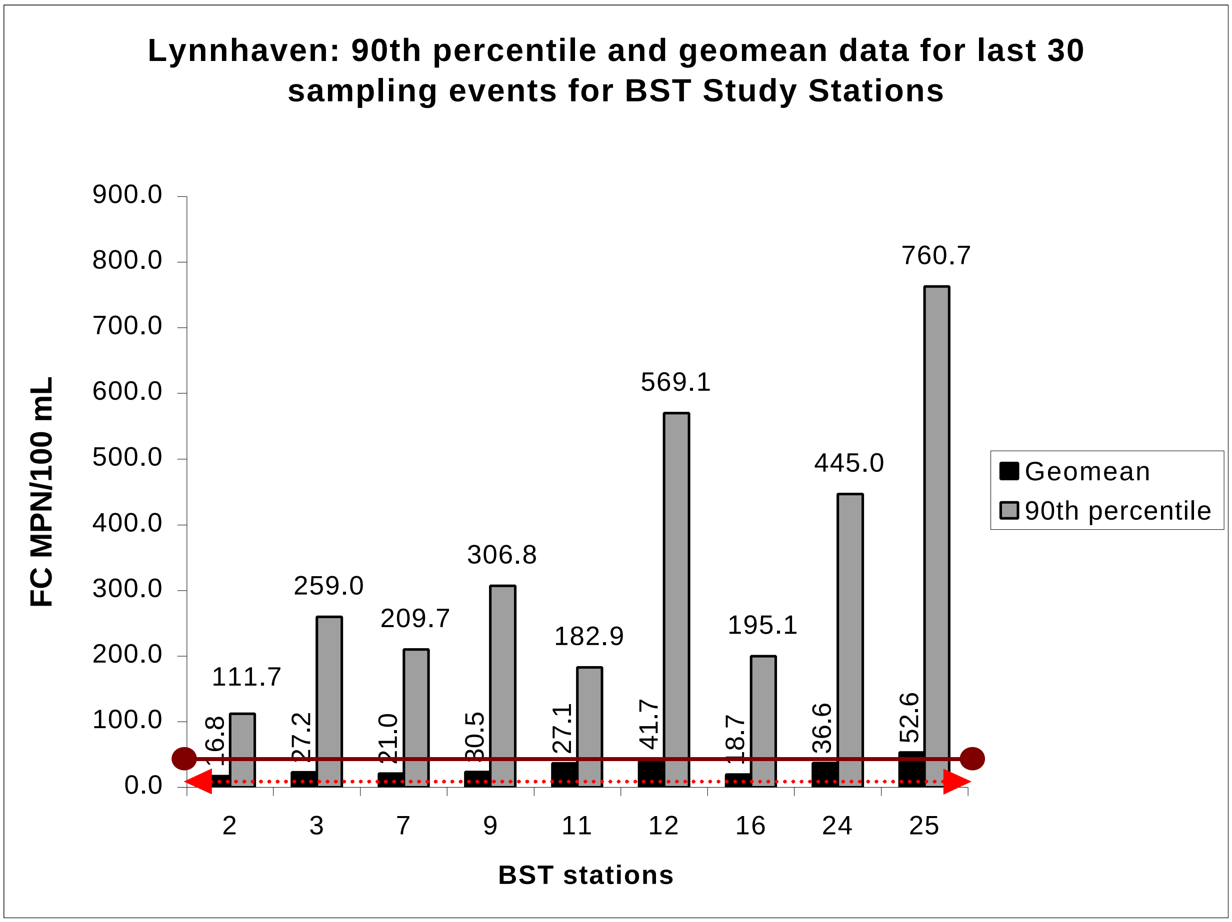


Figure 3-7 and Figure 3-8 show the moving geometric mean for the period of record in the Lynnhaven Bay and Broad/Linkhorn Bays respectively. These data illustrate the temporal and spatial trends in the data for an 18 year period. The data show that violations of the geometric mean standard are highly localized in the Broad and Linkhorn Bay watershed, but are ubiquitously distributed in the Lynnhaven Bay watershed. These data are consistent with the level of development in these watersheds.

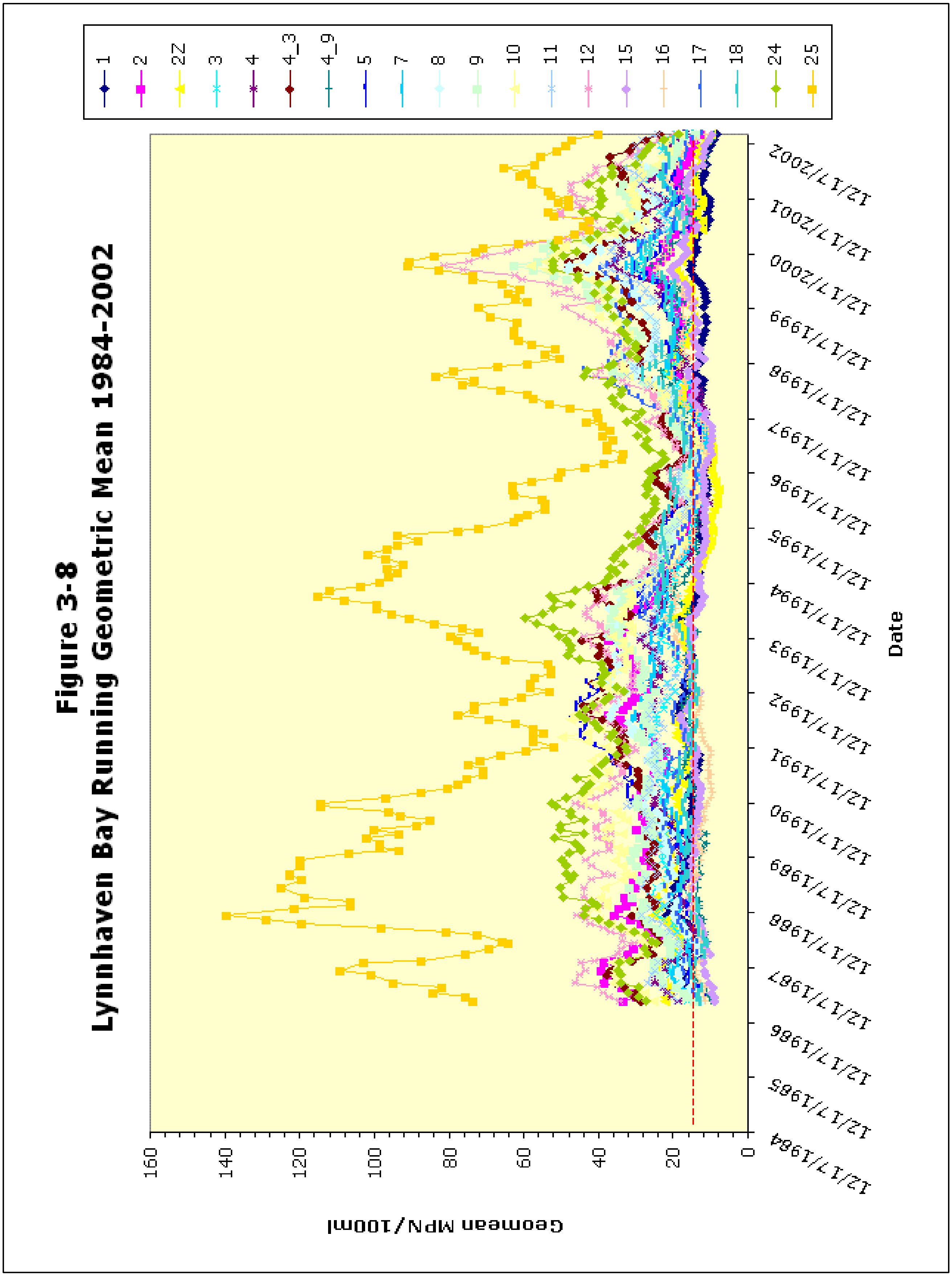


Figure 3-8
Lynnhaven Bay Running Geometric Mean 1984-2002
Geomean MPN/100ml
0
20
40
60
80
100
120
140
160
Date
12/17/1984
12/17/1985
12/17/1986
12/17/1987
12/17/1988
12/17/1989
12/17/1990
12/17/1991
12/17/1992
12/17/1993
12/17/1994
12/17/1995
12/17/1996
12/17/1997
12/17/1998
12/17/1999
12/17/2000
12/17/2001
12/17/2002
1
2
2Z
3
4
4_3
4_9
5
7
8
9
10
11
12
15
16
17
18
24
25

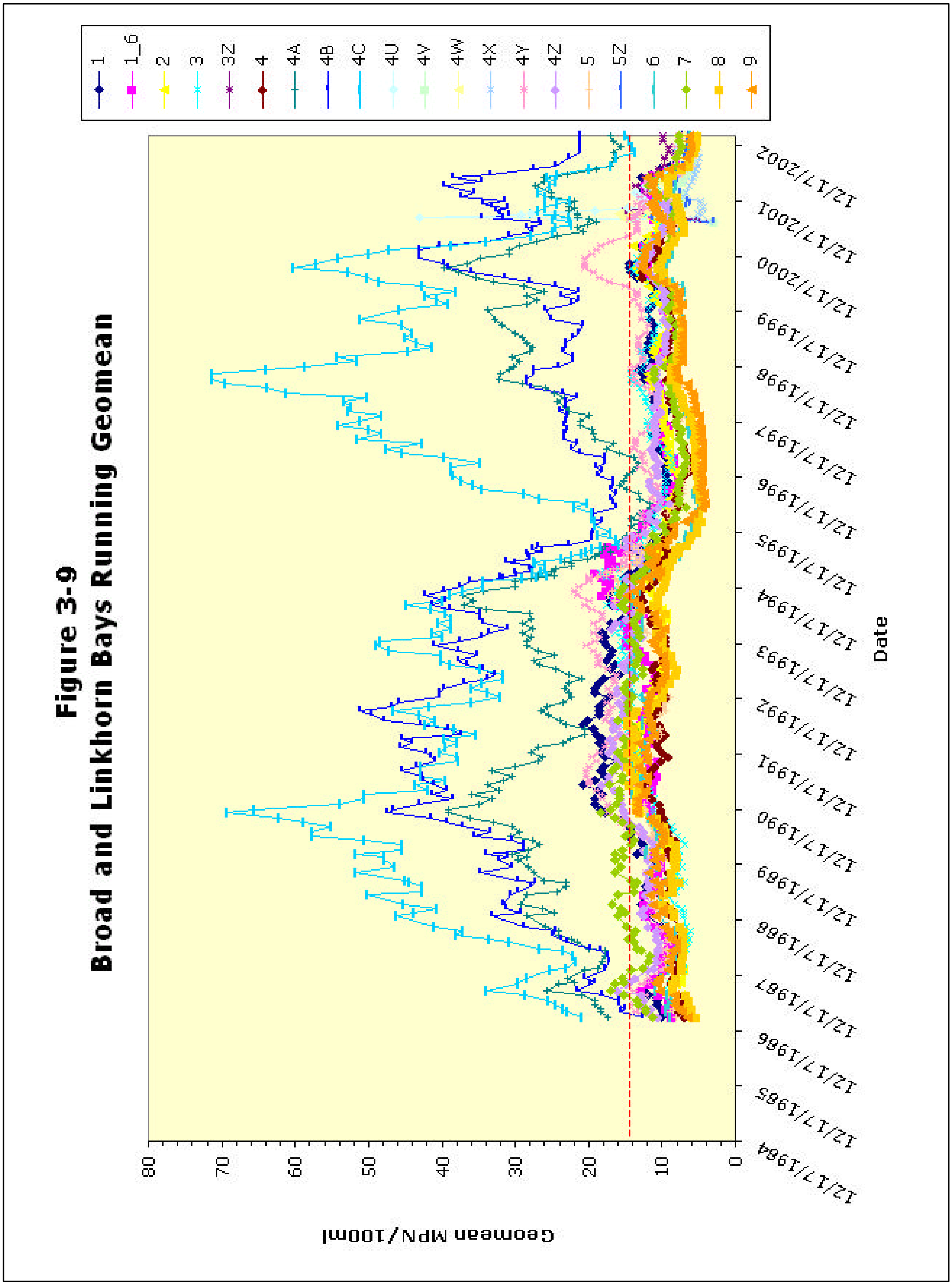


Figure 3-9
Broad and Linkhorn Bays Running Geomean
Geomean MPN/100ml
Date
0
10
20
30
40
50
60
70
80
12/17/1984
12/17/1985
12/17/1986
12/17/1987
12/17/1988
12/17/1989
12/17/1990
12/17/1991
12/17/1992
12/17/1993
12/17/1994
12/17/1995
12/17/1996
12/17/1997
12/17/1998
12/17/1999
12/17/2000
12/17/2001
12/17/2002
1
1_6
2
3
3Z
4
4A
4B
4C
4U
4V
4W
4X
4Y
4Z
5
5Z
6
7
8
9

4.0 Assessment of Bacteria Sources

There are several methods that are utilized to determine the potential sources of bacteria to the system. Chief among these are:

1. VADEQ Point Source Inventory to determine permitted point sources such as sewage treatment plants;
2. DSS Shoreline Survey to determine principal non-point sources such as failing septic systems and farm based non-point source operations; and,
3. bacterial source tracking to quantify source loadings from humans, livestock, and wildlife.

All of these are utilized in this report.

4.1 Point Source Contributions

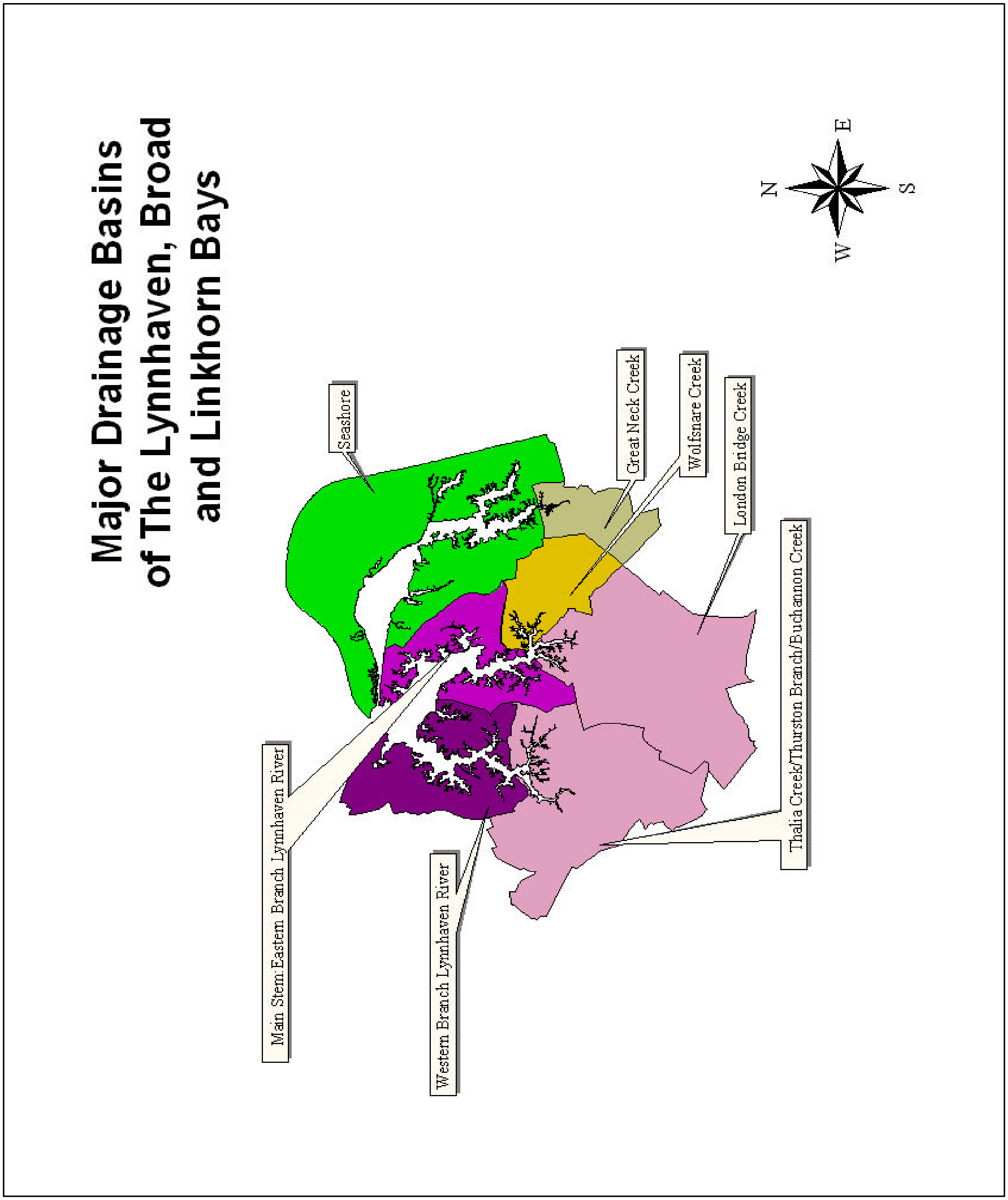
There are VPDES permitted point source contributions to the Lynnhaven Bay watershed from storm water discharge facilities located throughout the basin. These discharges are regulated by the DEQ through a Virginia Pollutant Discharge Elimination (VPDES) permit issued to the City of Virginia Beach. A map of the storm water service areas for the Lynnhaven Bay and Broad Bay are shown in Figure 4-1. An overview of the general types of BMP's located within these service areas is shown in Figure 4-2.

4.2 Non-Point Source Contributions

The shoreline survey is used as the primary source for indications of non-point source pollution due to the level of detail contained in the assessment potential sources in the watershed. This is accomplished through observation of direct and indirect discharges to the watershed. Such discharges include storm water systems, failing septic systems, waste water treatment plants (if any), as well as surface runoff from lawns and undeveloped landscapes. Figure 3-4 summarizes the results of the DSS sanitary shoreline survey dated February 1997 for the Lynnhaven Bay watershed. A copy of the textual portion of this survey has been included as Appendix A. The survey identified 26 sanitary sewage deficiencies, 7 industrial waste, 1 solid waste dumpsite, 7 boating related sources, 2 sites with a potential for pollution and 3 animal waste sources.

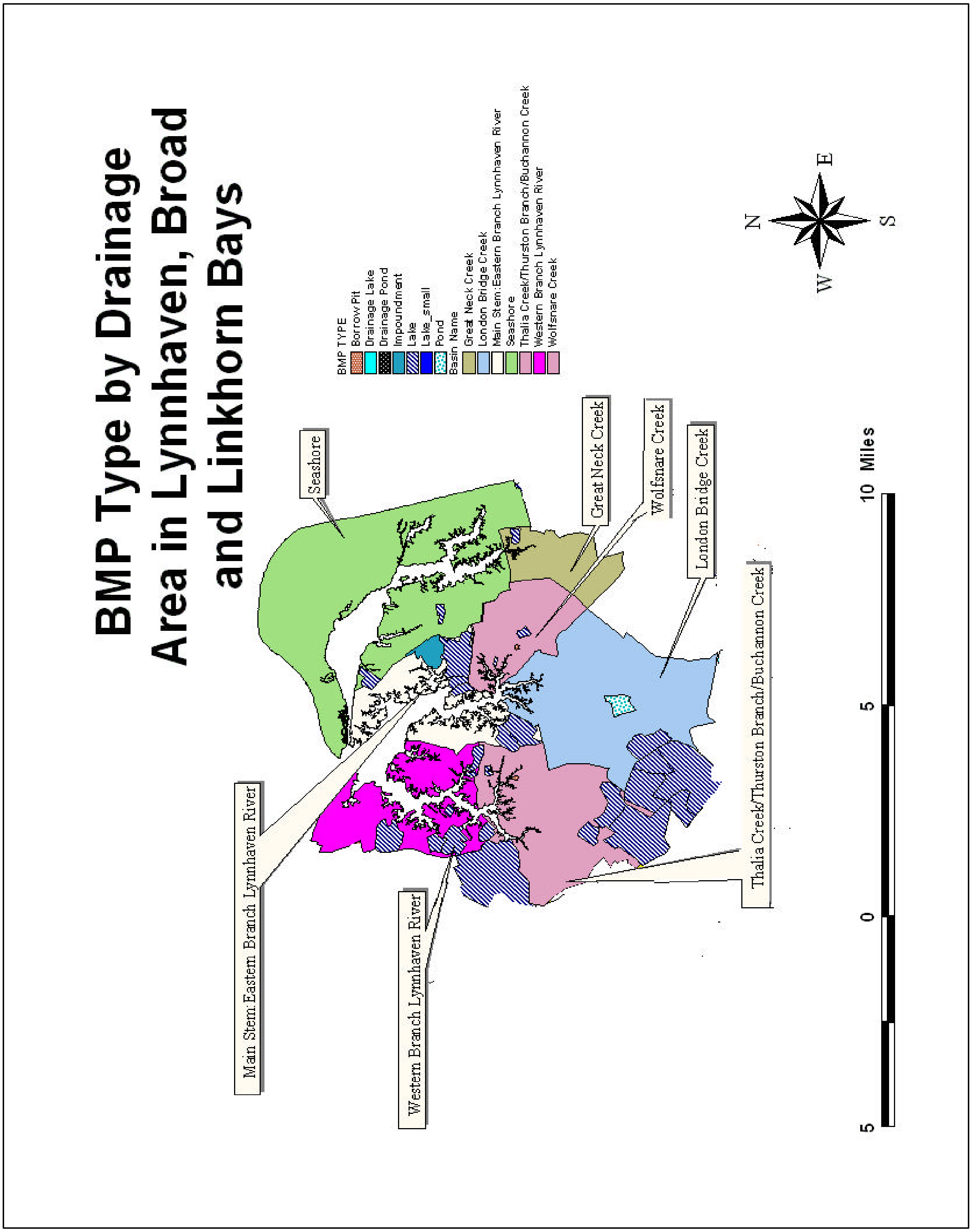
Generally, there are many avenues of non-point source pollution into watersheds. Some of these contributions such as those from wildlife, both mammalian and avian, are natural conditions and may represent a background level of bacterial loading. Other contributions such as those from mammalian and avian livestock result from runoff from pastureland, concentrated animal feeding operations, or livestock yards. Pet contributions usually occur through street and land runoff that may be collected into storm water systems and conveyed into Bays and tributary streams. Non-Point source contributions to the bacterial levels in the Lynnhaven Bay from human activities generally arise from failing septic systems and associated drain fields, moored or marina vessel discharges, storm

Figure 4-1



Major Drainage Basins
of The Lynnhaven, Broad
and Linkhorn Bays
Seashore
Great Neck Creek
Wolfsnare Creek
London Bridge Creek
Thalia Creek/Thurston Branch/Buchannon Creek
Western Branch Lynnhaven River
Main Stem:Eastern Branch Lynnhaven River
N
E
S
W

Figure 4-2


BMP Type by Drainage Area in Lynnhaven, Broad and Linkhorn Bays
BMP TYPE
Borrow Pit
Drainage Lake
Drainage Pond
Impoundment
Lake
Lake_small
Pond
Basin Name
Great Neck Creek
London Bridge Creek
Main Stem:Eastern Branch Lynnhaven River
Seashore
Thalia Creek/Thurston Branch/Buchannon Creek
Western Branch Lynnhaven River
Wolfsnare Creek
Seashore
Great Neck Creek
Wolfsnare Creek
London Bridge Creek
Thalia Creek/Thurston Branch/Buchannon Creek
Main Stem:Eastern Branch Lynnhaven River
Western Branch Lynnhaven River
N
E
S
W
5
0
5
10 Miles

water management facilities, pump station failures and ex-filtration from sewer systems. In the Lynnhaven, Broad and Linkhorn Bay watershed there is a municipal sewer system network that conveys human effluent to the Hampton Roads Sanitation District (HRSD) treatment plants and a storm water management system comprised of approximately 979 permitted out falls to the Lynnhaven watershed. The sewer system network has a record of frequent discharges to the adjacent storm water system and to state waters on an annual basis. These discharges are due to gravity sewer line and house clean out leaks and spills, damage to sanitary sewer facilities caused by construction activities, malfunctions and failures of force mains, pump stations and similar problems. Isolated areas of suburban homes, the largest concentration of which are located at Little Neck Point in Lynnhaven Bay, utilize septic systems and drain fields for waste treatment. Malfunctions associated with these facilities may act as another source of human fecal coliform bacteria to the Bays. These ongoing source contributions may possibly receive augmentation from recreation vessel discharges. It should be noted that the City of Virginia Beach has had an on-going effort to address the sewer and storm water systems in place since 1977. The change in areas served by municipal sewer from 1972 to 2002 is shown in Figures 4-3 and 4-4.

4.3 Bacterial Source Tracking

BST is used to identify and quantify bacterial contributions from anthropogenic and background sources, such as wildlife, for which no precise loading value exists. The nine stations that were selected as a TMDL study for this TMDL were also evaluated for source characterization through a process called BST. Twelve months of sampling was conducted from September 2001 through August 2002 to obtain the necessary fecal coliform isolates. The TMDL study BST analysis uses the Antibiotic Resistance Approach (ARA), to partition the sources of fecal coliform to the water body. ARA uses fecal streptococcus or *Escherichia coli (E. Coli)* and patterns of antibiotic resistance for partitioning sources. The premise is that human, domestic animal, and wild animal fecal bacteria will have significantly different patterns of resistance to the battery of antibiotics used in this test. The ARA determines the percent loading per source category to the water. The five major source categories that were used in the TMDL study were human, pets, livestock, mammalian wildlife, and birds.

Figure 3-4 shows the TMDL study stations which are also the BST monitoring stations for the Lynnhaven Bay watershed. The full BST report for the Lynnhaven Bay is located in Appendix B. The data developed for the Lynnhaven Bay watershed indicate that the contribution in virtually all of the closure areas may be comprised of as much as 25% human origin. Second to human, avian and wildlife contributions from naturally occurring populations of waterfowl and wildlife are the largest components of the bacterial loading to the system. The monthly data by closure area is shown in the following pages both in graphical and tabular form.

Figure 4-3
City of Virginia Beach: Areas Served
by Municipal Sewer in 1972 (in Green)

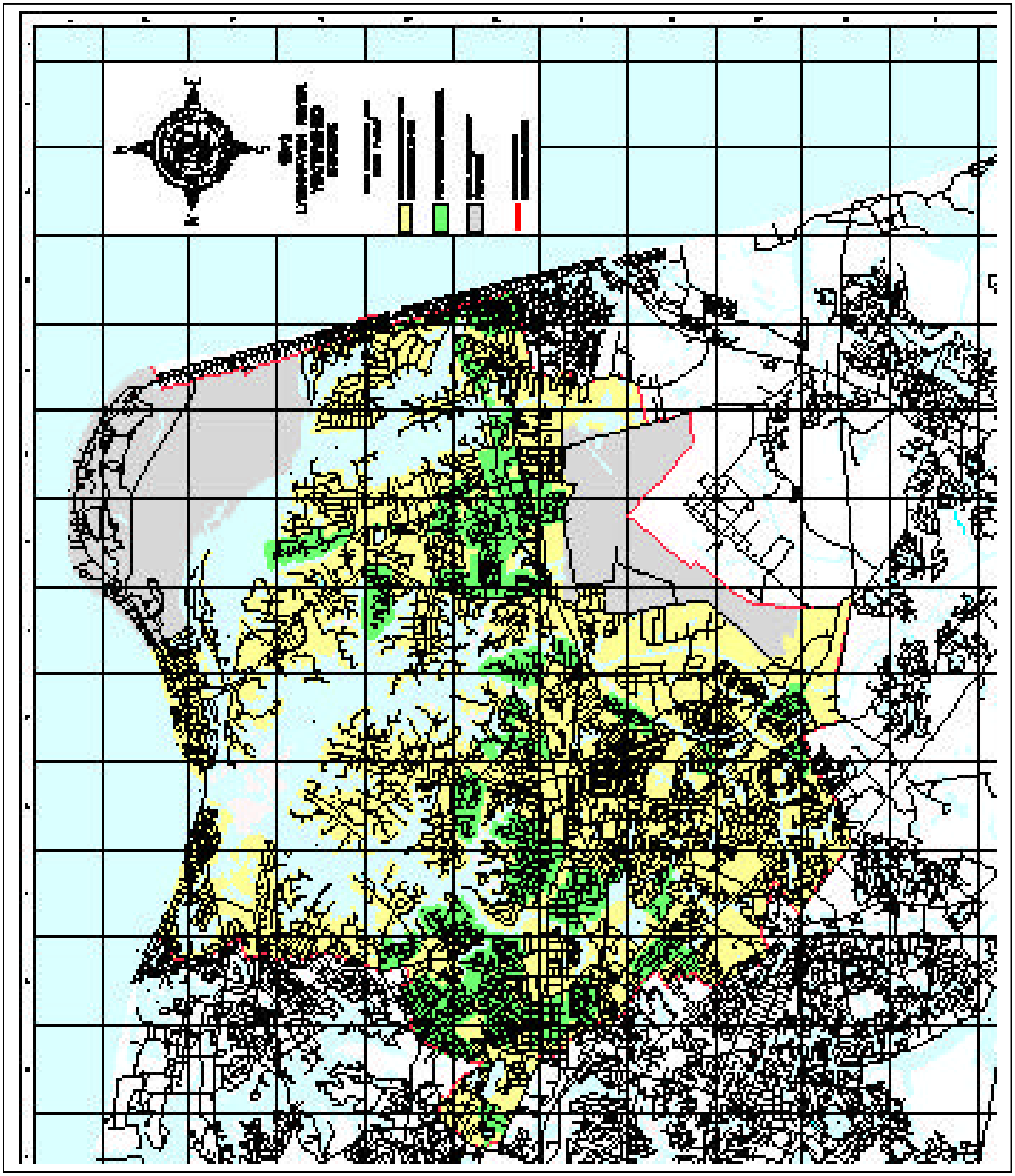
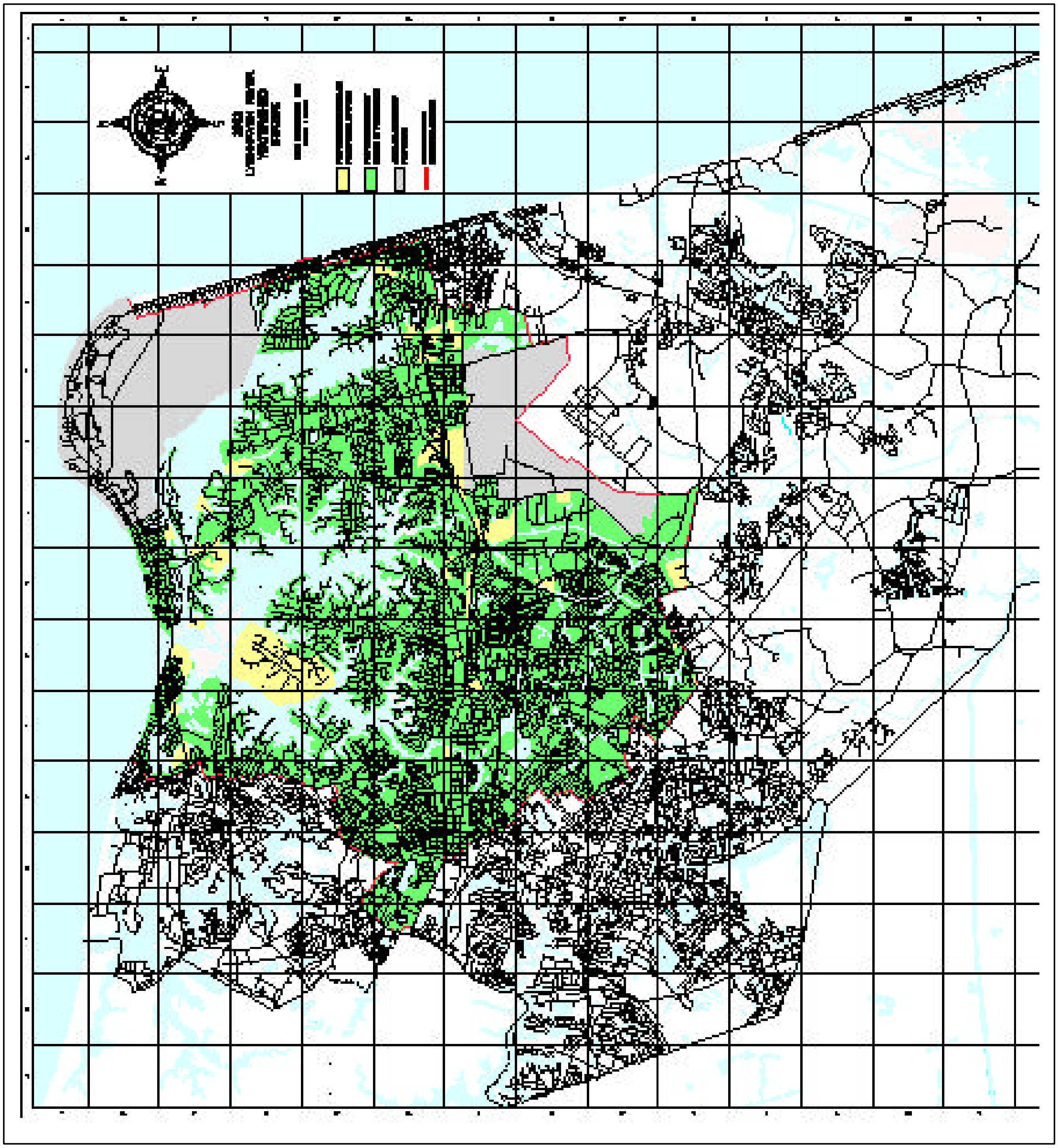


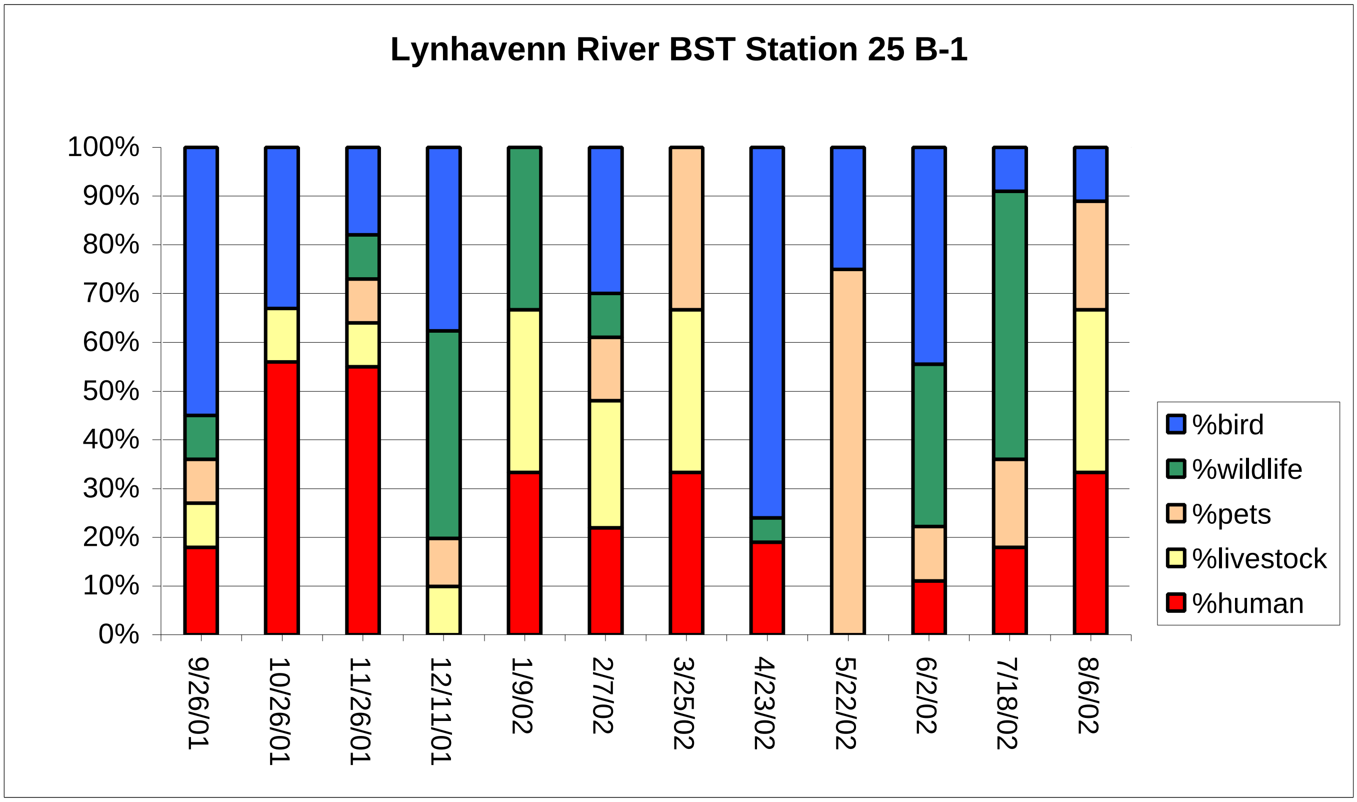
Figure 4-4
City of Virginia Beach: Areas Served by Municipal Sewer in 2002 (in Green)



a). DSS Growing Area 71, Closure Area 25B, Broad Bay Station 1

As shown in Figure 4-4 and its associated table, the dominant contributing source to the bacterial levels at this station are bird and human in origin. Pets provide the dominant contribution in ~~June~~ May, birds in April, September and June. Humans dominated in October and November. A human signature was present in all months except May and December.

Figure 4-4

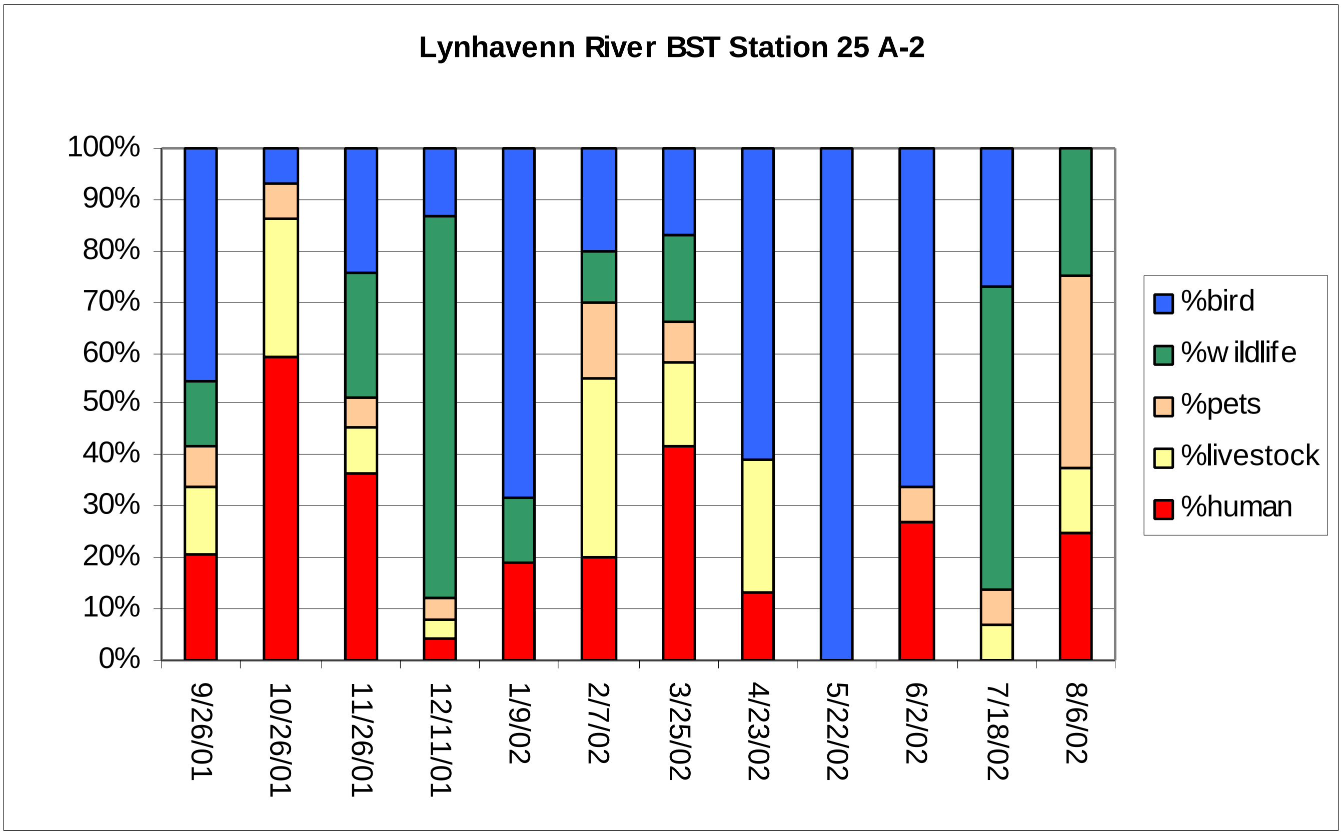


DATE	BACTERIA MPN/100ML	BIRDS	HUMAN	LIVESTOCK	PETS	WILDLIFE
9/26/2001	3	55	18	9	9	9
10/26/2001	3	33	56	11	0	0
11/26/2001	3	18	55	9	9	9
12/11/2001	58	38	0	10	10	43
1/9/2002	2	0	36	33	0	33
2/7/2002	14	30	22	26	13	9
3/25/2002	1	0	33	33	33	0
4/23/2002	9	76	19	0	0	5
5/22/2002	2	25	0	0	75	0
6/2/2002	2	44	11	0	11	33
7/18/2002	2	9	18	0	18	55
8/6/2002	4	11	33	33	22	0
Average		28.3	25.1	13.7	15.8	16.3

b). DSS Growing Area 70, Closure Area 25A, Lynnhaven Bay Station 2.

Figure 4-5 and its associated table, shows that the dominant contributing source to the bacterial levels of Station 2 is bird in origin in January, April, May, June and September. A human signature is present in all months except May and July. The human signature dominates in October, November and March. Pets were a significant contributor in August. Wildlife dominated in December and July.

Figure 4-5

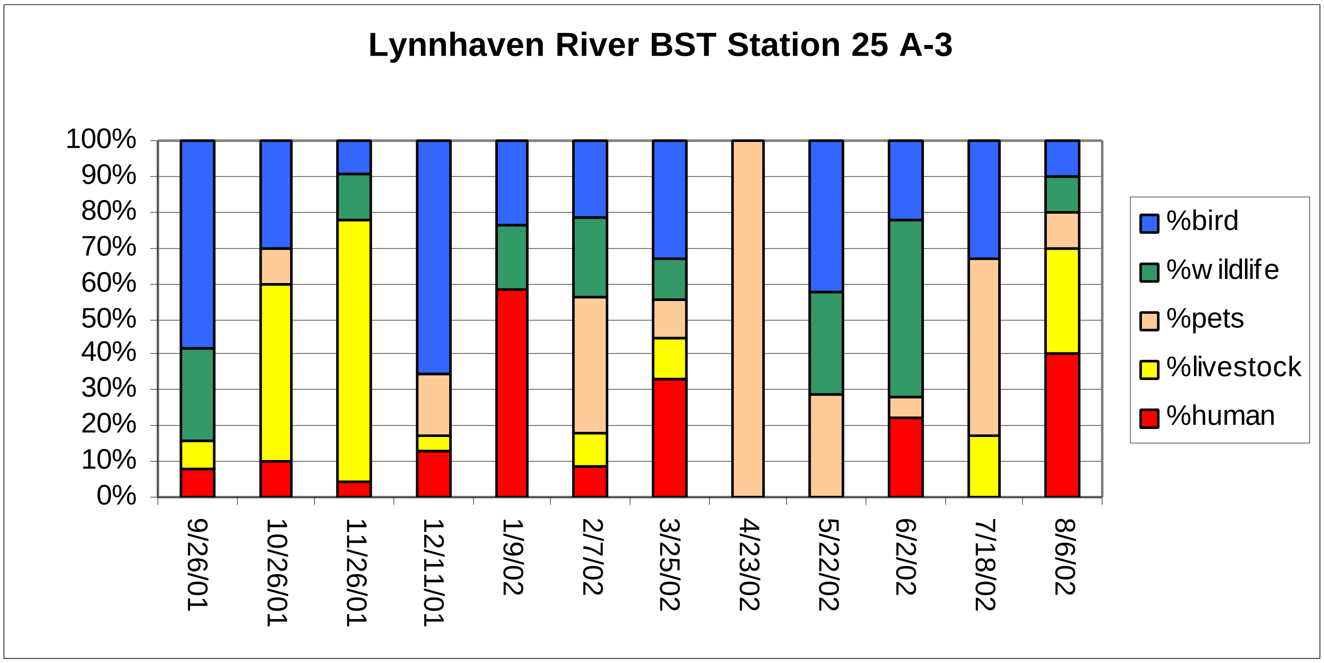


DATE	BACTERIA MPN/100ML	BIRDS	HUMAN	LIVESTOCK	PETS	WILDLIFE
9/26/2001	11	46	21	13	8	13
10/26/2001	5	7	60	27	7	0
11/26/2001	30	24	36	9	6	24
12/11/2001	146	13	4	4	4	74
1/9/2002	13	69	19	0	0	13
2/7/2002	23	20	20	35	15	10
3/25/2002	3	17	42	17	8	17
4/23/2002	6	61	13	26	0	0
5/22/2002	0	100	0	0	0	0
6/2/2002	5	67	27	0	7	0
7/18/2002	5	27	0	7	7	60
8/6/2002	3	0	25	13	38	25
Average		37.6	22.3	12.6	8.3	19.7

c). DSS Growing Area 70, Closure Area 25A, Lynnhaven Bay Station 3

Figure 4-6 and its associated table show that the dominant contributing source to the bacterial levels of Station 3 is livestock in origin for October and November, human in origin in January and August, and bird in origin in September and December. Pets dominated in February, April and July.

Figure 4-6

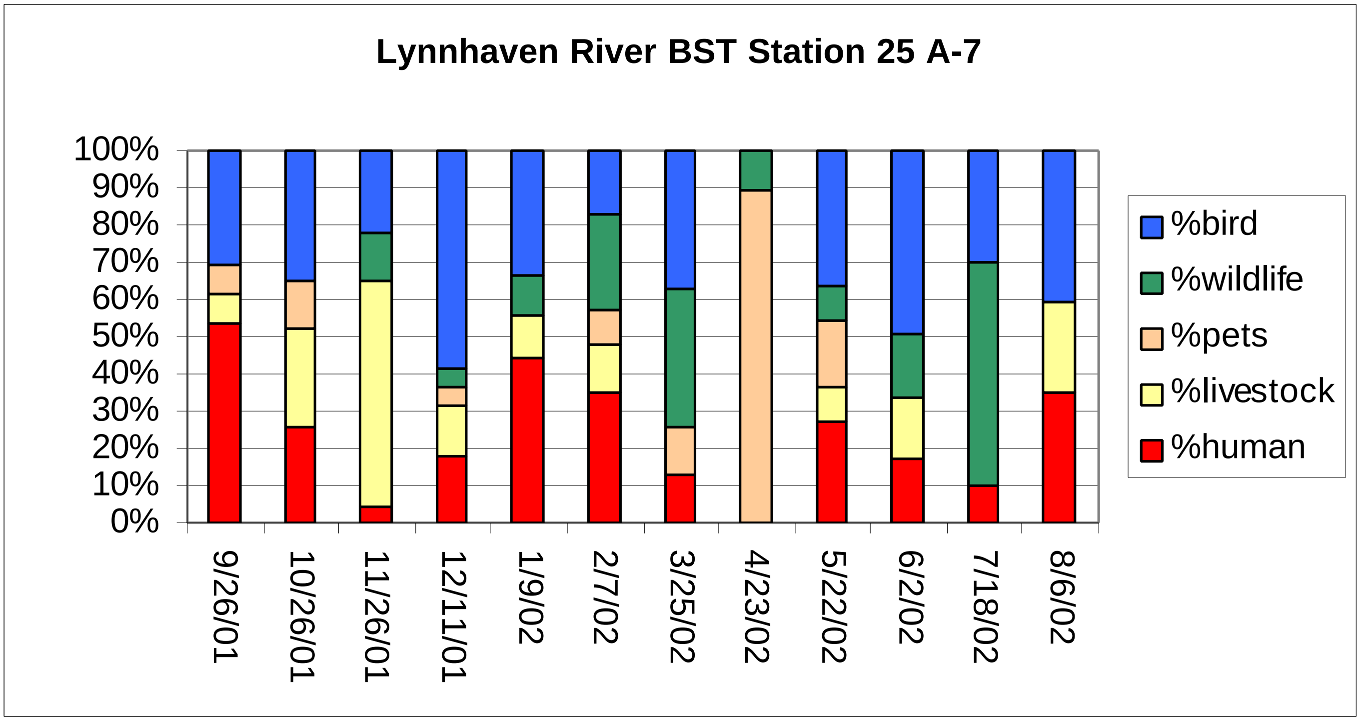


DATE	BACTERIA MPN/100ML	BIRDS%	HUMAN%	LIVESTOCK %	PETS%	WILDLIFE%
9/26/2001	3	58	8	8	0	25
10/26/2001	4	30	10	50	10	0
11/26/2001	7	9	4	74	0	13
12/11/2001	90	65	13	4	17	0
1/9/2002	14	24	59	0	0	18
2/7/2002	15	22	9	9	39	22
3/25/2002	3	33	33	11	11	11
4/23/2002	7	0	0	0	100	0
5/22/2002	3	43	0	0	29	29
6/2/2002	6	22	22	0	6	50
7/18/2002	2	33	0	17	50	0
8/6/2002	5	10	40	30	10	10
Average		29.1	16.5	16.9	22.7	14.8

d). DSS Growing Area 70, Closure Area 25A, Lynnhaven Bay Station 7

Figure 4-5 and its associated table, shows that the dominant contributing source to the bacterial levels of Station 7 of Lynnhaven Bay is due to birds in December, March, May, June and August. A human signature is present in all months except April, and dominates in September, February and January. Pets dominate in April.

Figure 4-7

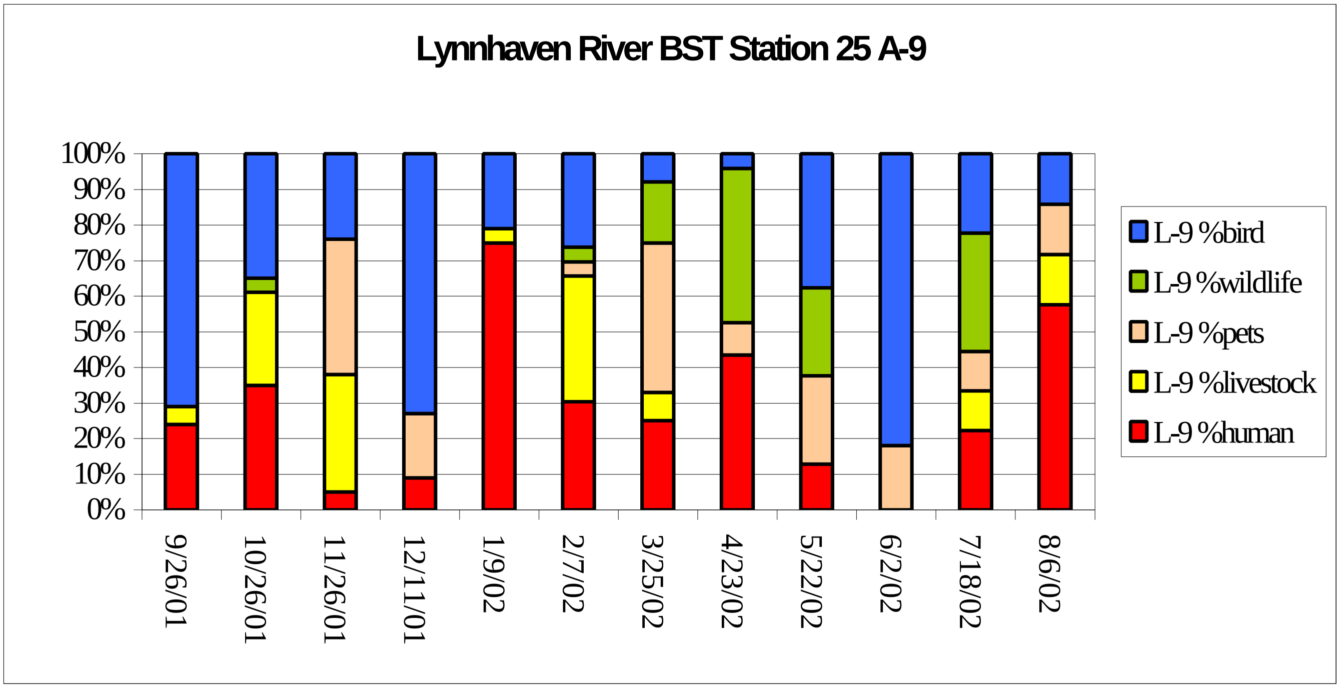


DATE	BACTERIA MPN/100ML	BIRDS	HUMAN	LIVESTOCK	PETS	WILDLIFE
9/26/2001	5	31	54	8	8	0
10/26/2001	10	35	26	26	13	0
11/26/2001	5	22	4	61	0	13
12/11/2001	60	59	18	14	5	5
1/9/2002	17	33	44	11	0	11
2/7/2002	30	17	35	13	9	26
3/25/2002	2	38	13	0	13	38
4/23/2002	8	0	0	0	89	11
5/22/2002	5	36	27	9	18	9
6/2/2002	1	50	17	17	0	17
7/18/2002	3	30	10	0	0	60
8/6/2002	7	41	35	24	0	0
Average		32.67	23.58	15.25	12.92	15.83

e). DSS Growing Area 70, Closure Area 25A, Lynnhaven Bay Station 9

Figure 4-6 and its associated table shows that the dominant source to the bacterial levels of Station 9 is dominated by human sources in January, April and August. Birds were the dominant source in September, December, May and June. Birds were co-dominant in February. Pets were dominant sources in November and March. A human signature was present in all months of the study period.

Figure 4-8

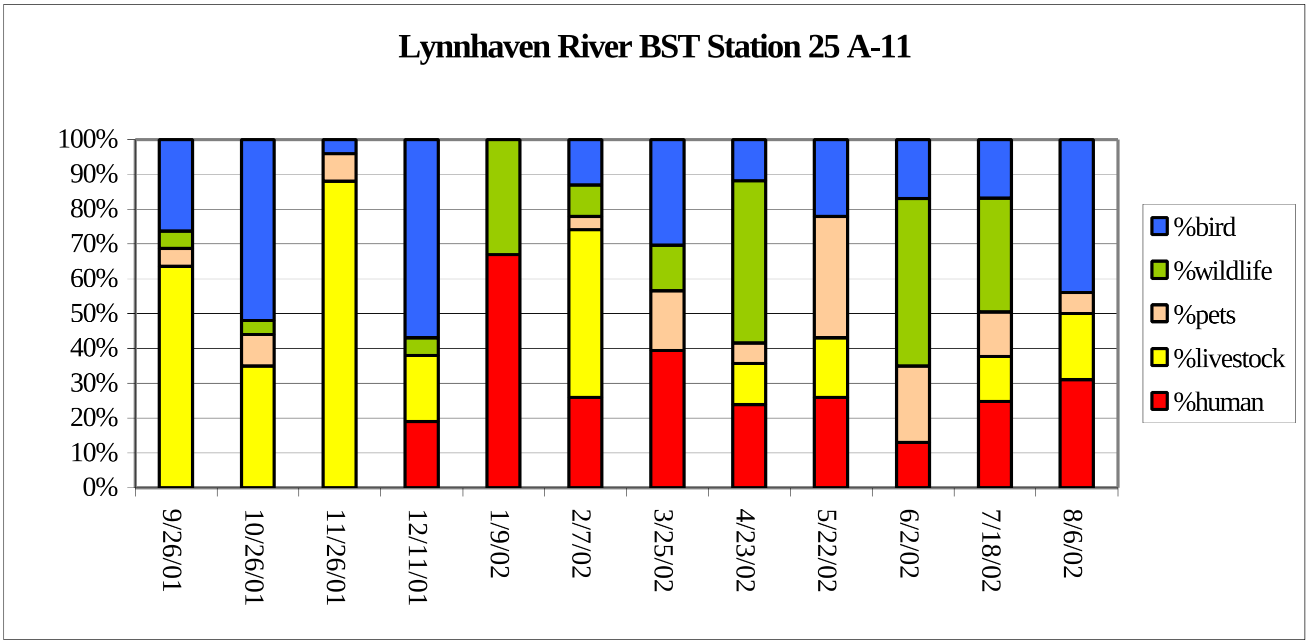


DATE	BACTERIA MPN/100ML	BIRDS	HUMAN	LIVESTOCK	PETS	WILDLIFE
9/26/2001	11.5	71	24	5	0	0
10/26/2001	8	35	35	26	0	4
11/26/2001	5	24	5	33	38	0
12/11/2001	87	73	9	0	18	0
1/9/2002	25	21	75	4	0	0
2/7/2002	12	26	30	35	4	4
3/25/2002	4	8	25	8	42	17
4/23/2002	15	4	43	0	9	43
5/22/2002	5	38	13	0	25	25
6/2/2002	4	82	0	0	18	0
7/18/2002	3	22	22	11	11	33
9/26/2001	4	14	57	14	14	0
Average		34.8	28.7	11.3	14.9	10.5

f). DSS Growing Area 70, Closure Area 25A, Lynnhaven Bay Station 11

Figure 4-9 and its associated table, shows that the dominant contributing source to the bacterial levels of Station 11 in Lynnhaven Bay is livestock in origin for September, November and February. Birds dominated in October, December and August. Pets dominated only in May. Wildlife dominated in June and July.

Figure 4-9

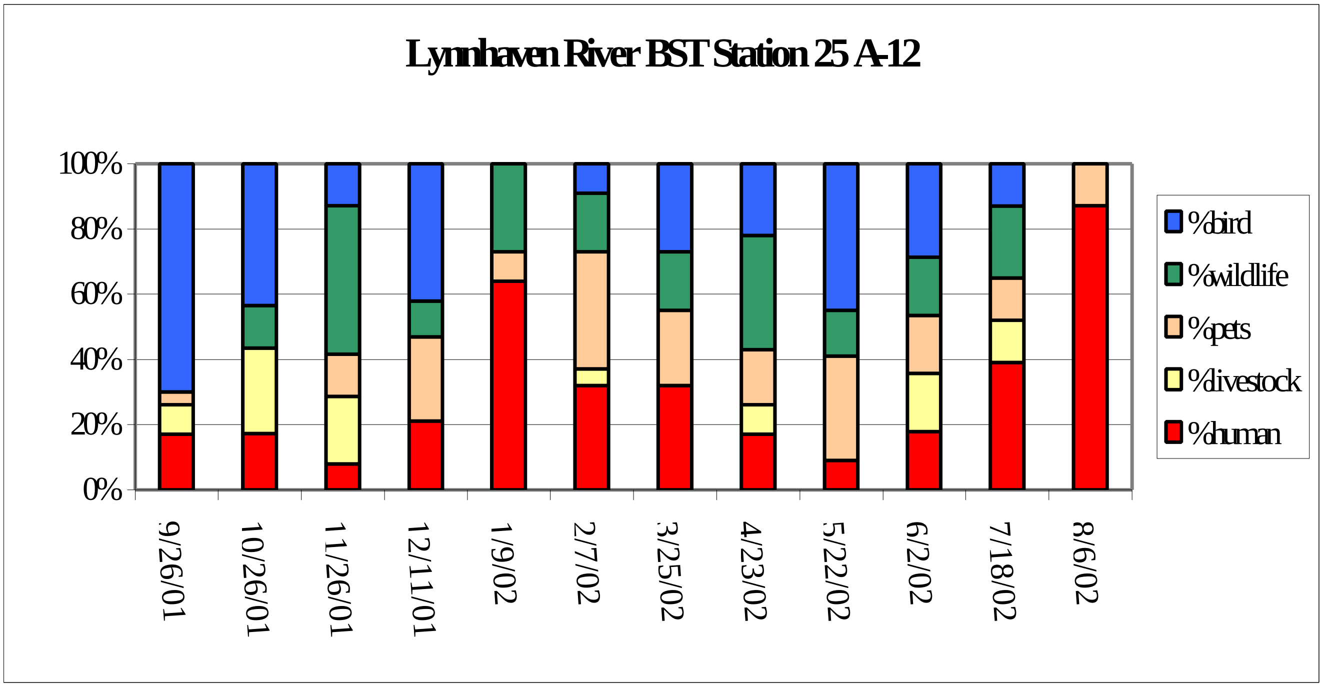


DATE	BACTERIA MPN/100ML	BIRDS	HUMAN	LIVESTOCK	PETS	WILDLIFE
9/26/2001	7	26	0	63	5	5
10/26/2001	23	52	0	35	9	4
11/26/2001	28	4	0	88	8	0
12/11/2001	244	57	19	19	0	5
1/9/2002	7	0	67	0	0	33
2/7/2002	63	13	26	48	4	9
3/25/2002	12	30	39	0	17	13
4/23/2002	59	12	24	12	6	47
5/22/2002	86	22	26	17	35	0
6/2/2002	12	17	13	0	22	48
7/18/2002	8	17	25	13	13	33
8/6/2002	8	44	31	19	6	0
Average		24.5	22.5	26.17	10.42	16.42

g). DSS Growing Area 70, Closure Area 25A, Lynnhaven Bay Station 12

Figure 4-10 and its associated table shows that the dominant contributing source to the bacterial levels of the Lynnhaven Bay at Station 12 human in origin for January, February, March, July and August. Birds dominated in September, October, December, May and June. Wildlife dominated in November and April. A human signature was present in all months of the study period.

Figure 4-10

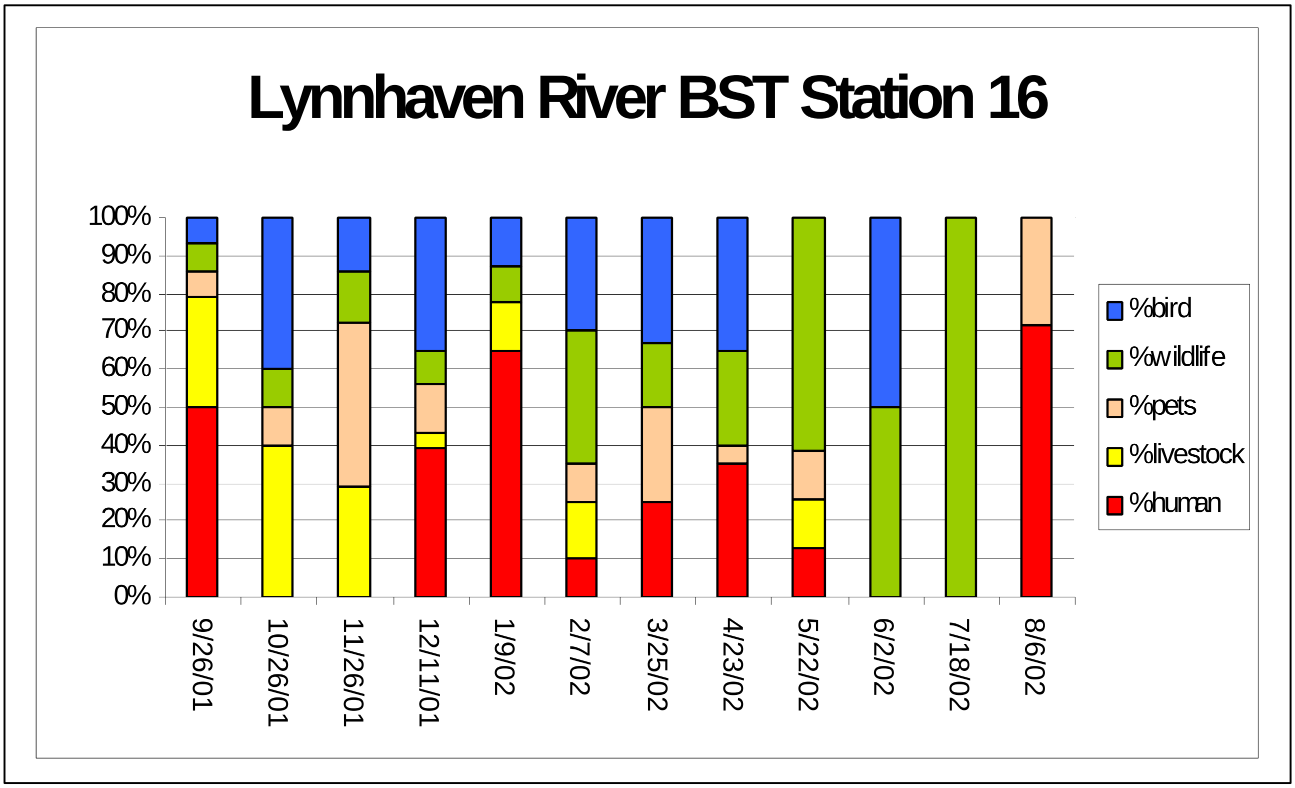


DATE	BACTERIA MPN/100ML	BIRDS	HUMAN	LIVESTOCK	PETS	WILDLIFE
9/26/2001	21	70	17	9	4	0
10/26/2001	20	43	17	26	0	13
11/26/2001	9	13	8	21	13	46
12/11/2001	180	42	21	0	26	11
1/9/2002	23	0	64	0	9	27
2/7/2002	21	9	32	5	36	18
3/25/2002	6	27	32	0	23	18
4/23/2002	31	22	17	9	17	35
5/22/2002	19	45	9	0	32	14
6/2/2002	5	29	18	18	18	18
7/18/2002	8	13	39	13	13	22
8/6/2002	7	0	88	0	13	0
Average		26.08	30.17	8.42	17	18.5

h). DSS Growing Area 70, Closure Area 25A, Lynnhaven Bay Station 16

Figure 4-11 and its associated table show that the dominant contributing source to the bacterial levels at Station 16 in Lynnhaven Bay was human in origin for September, December January and August. Wildlife dominated in May, June and July. Pets were dominant in November, livestock in October and Birds in June.

Figure 4-11

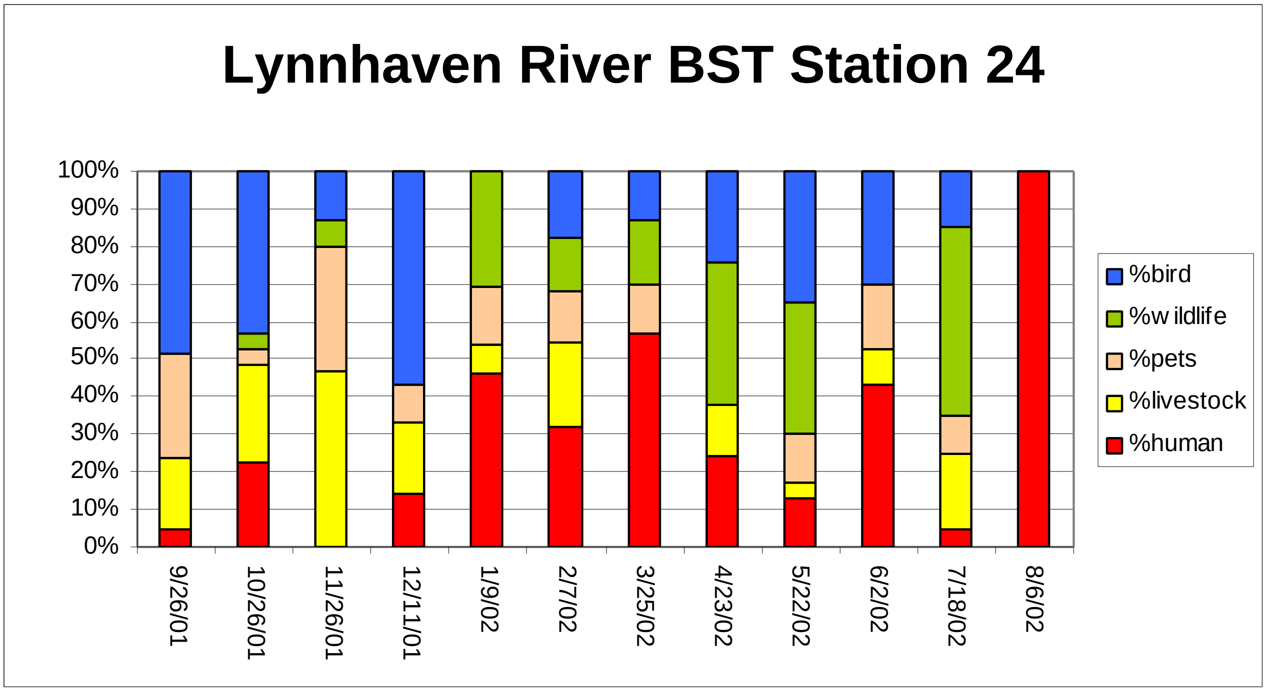


DATE	BACTERIA MPN/100ML	BIRDS	HUMAN	LIVESTOCK	PETS	WILDLIFE
9/26/2001	5	7	50	29	7	7
10/26/2001	3	40	0	40	10	10
11/26/2001	2	14	0	29	43	14
12/11/2001	67	35	39	4	13	9
1/9/2002	18	13	65	13	0	9
2/7/2002	22	30	10	15	10	35
3/25/2002	2	33	25	0	25	17
4/23/2002	8	35	35	0	5	25
5/22/2002	3	0	13	13	13	63
6/2/2002	1	50	0	0	0	50
7/18/2002	1	0	0	0	0	80
9/26/2001	1	0	50	0	20	0
Average		21.42	23.92	11.92	12.17	26.58

h). DSS Growing Area 70, Closure Area 25A, Lynnhaven Bay Station 24

Figure 4-12 and its associated table show that the dominant contributing source to the bacterial levels for Station 24 of Lynnhaven Bay is bird in origin for September, October, December and May. Human contributions were present in 11 of 12 months and dominant in January, February, March, June and August. Wildlife dominated in April and July.

Figure 4-12

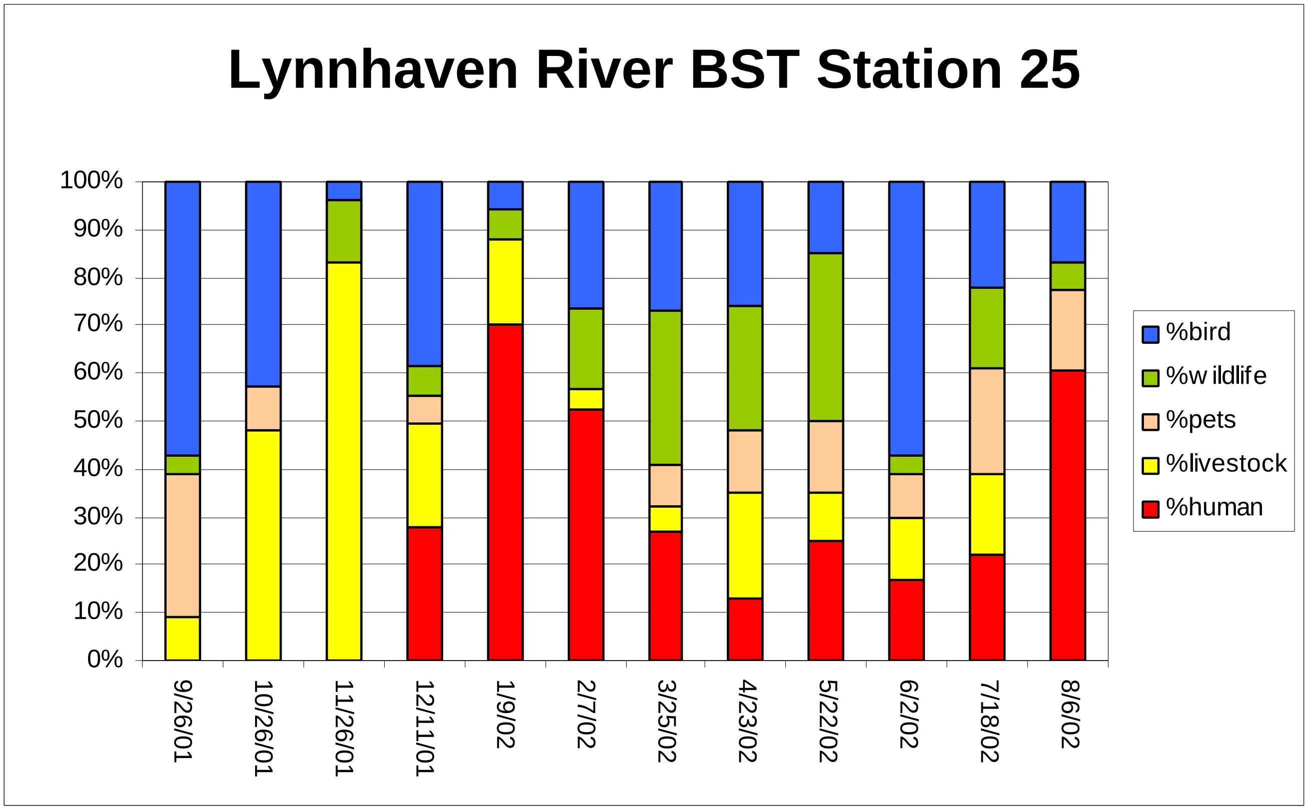


DATE	BACTERIA MPN/100ML	BIRDS	HUMAN	LIVESTOCK	PETS	WILDLIFE
9/26/2001	17	43	4	17	25	0
10/26/2001	16	43	22	26	4	4
11/26/2001	4	13	0	47	33	7
12/11/2001	514	57	14	19	10	0
1/9/2002	33	0	46	8	15	31
2/7/2002	52	18	32	23	14	14
3/25/2002	7	13	57	0	13	17
4/23/2002	65	24	24	14	0	38
5/22/2002	9	35	13	4	13	35
6/2/2002	5	30	43	9	17	0
7/18/2002	5	15	5	20	10	50
8/6/2002	2	0	100	0	0	0
Average		24.25	30	15.58	12.83	16.33

i). DSS Growing Area 70, Closure Area 25A, Lynnhaven Bay Station 25

Figure 4-13 and its associated table shows that the dominant contributing source to the bacterial levels for Station 25 of Lynnhaven Bay is human in January, February, July and August. Livestock appear as the dominant source in October and November. Birds were dominant in September, December and June. A human signature was present in all months except September, October and November.

Figure 4-13



DATE	BACTERIA MPN/100ML	BIRDS	HUMAN	LIVESTOCK	PETS	WILDLIFE
9/26/2001	44	57	0	9	30	4
10/26/2001	20	43	0	48	9	0
11/26/2001	78	4	0	83	0	13
12/11/2001	765	39	28	22	6	6
1/9/2002	50	6	71	18	0	6
2/7/2002	197	26	52	4	0	17
3/25/2002	19	27	27	5	9	32
4/23/2002	145	26	13	22	13	26
5/22/2002	31	15	25	10	15	35
6/2/2002	31	57	17	13	9	4
7/18/2002	15	22	22	17	22	17
8/6/2002	4	17	61	0	17	6
Average		28.25	26.33	20.92	10.83	13.83

In summation these data indicate that human contributions to the Lynnhaven Bay, Broad and Linkhorn Bay and their tributaries represent a relative average of 25% of the bacteria contribution to the shellfish closure areas. Additional sources in order of relative contributions are birds 29%, wildlife 17%, livestock 15%, and pets 14%. This result is supported by other field investigations. The presence of bacteria of human origin in any water body is a source of concern from a public health perspective for both shellfish consumption and recreational use. Having determined both the in stream bacterial concentrations and the relative probable source contributions to the Lynnhaven Bay shellfish closure a TMDL for each of these areas can be developed.

5.0 TMDL Development

<u>5.1 Simple Modeling Approach(Tidal Volumetric Model)</u>:

Personnel from EPA, Virginia DEQ, Virginia Department of Conservation and Recreation (DCR), Maryland Department of the Environment (MDE), Virginia DSS, Virginia Institute of Marine Sciences (VIMS), United States Geological Survey, Virginia Polytechnic University, James Madison University, and Tetra Tech composed the shellfish TMDL workgroup and developed a procedure for developing TMDLs using a simple approach. The goal of the procedure is to use BST data, in conjunction with shoreline surveys and other data, to determine the potential sources of fecal coliform violations and use ambient water quality data to determine the load reductions needed to attain the applicable criteria. The Lynnhaven, Broad and Linkhorn Bay watershed meets the criteria for using the simple modeling approach because of the following conditions:

- The watershed is hydrologically simple (i.e. limited flushing due to constriction at the mouth of Lynnhaven Bay).
- Land use is more homogenous (limited variability in land use patterns due to the dominance of single family homes)
- The area is served by a municipal sewer system that discharges treated effluent outside the basin
- Topography is relatively flat and runoff is collected in a storm water system of pipes, natural and manmade channels, and BMPs.

5.2 The TMDL Calculation:

The most recent 30-months of data overlapping the end of the TMDL study in August of 2002 have been reviewed to determine the loading to the water body. The approach insures compliance with the 90^{th} percentile and geometric mean criteria. The geometric mean loading is based on the most recent 30-month geometric mean of fecal coliform. The load is also quantified for the 90^{th} percentile of the 30-month grouping.

5.2.1. Geometric Mean Analysis:

The geometric mean load for each shellfish closure area at a representative monitoring station is determined by multiplying the geometric mean concentration based on the most recent 30 month period of record by the volume of the water. The acceptable load is then determined by multiplying the geometric mean criteria by the volume of the water. The load reductions needed for the attainment of the geometric mean are then determined by subtracting the acceptable load from the geometric mean load. Calculations of the geometric mean loads and allowable geometric mean loads are shown in Tables 5-1 and 5-2.

Example : (Geometric Mean Value MPN/100ml) x (volume) = Existing Load

(Criteria Value 14 MPN/100ml) x (volume) = Allowable Load

Existing Load – Allowable Load = Load Reduction

The closure areas in the Lynnhaven Bay are not characterized based on one monitoring station at the downstream terminus of the area (see Figure 3-4). Rather all stations reflect a condition of non-compliance with the water quality standard for bacteria in shellfish waters. To facilitate an effective assignment of the appropriate level of protection for this system and that of Broad and Linkhorn Bays, the water quality data was averaged across all stations in the watershed. This treats high and low values equally and provides a target that can be easily comprehended and uniformly implemented while retaining the necessary protection for the affected waters

Table 5-1 Geometric Mean Calculations for the Lynnhaven Bay TMDL

AVERAGE GEO- METRIC MEAN AREA 25A	SEGMENT VOLUME (CUBIC METERS)	VOLUME X GEO – MEAN = EXISTING LOAD	VOLUME X CRITERIA (14MPN/100ML) = ALLOWED LOAD	(ALLOWED LOAD)– (EXISTING LOAD)	REQUIRED REDUCTION IN PERCENT
25	**5,400,779**	**1.35E+12**	**7.56E+11**	**5.94E+11**	**56.0%**

Table 5-2 Geometric Mean Calculations for the Broad and Linkhorn Bays TMDL

AVERAGE GEO- METRIC MEAN AREA 25 B	SEGMENT VOLUME (CUBIC METERS)	VOLUME X GEO – MEAN = EXISTING LOAD	VOLUME X CRITERIA (14MPN/100ML) = ALLOWED LOAD	(ALLOWED LOAD)– (EXISTING LOAD)	REQUIRED REDUCTION IN PERCENT
10.9	**688,472**	**7.29E+10**	**9.36E+10**	**0.0**	**0%**

5.2.2. 90th Percentile Analysis:

The 90th percentile load is determined by multiplying the 90th percentile concentration, based on the most recent 30 month period of record, by the volume of the water. The acceptable load us determined by multiplying the 90th percentile criteria by the volume of the water. The load reductions needed for the attainment of the 90th percentile criteria are determined by subtracting the acceptable load from the 90th percentile load. These are shown in Tables 5-3 and 5-4. The more stringent reduction between the two methods is used for developing the TMDL.

Table 5-3 90th Percentile Calculations for the Lynnhaven Bay TMDL

AVERAGE90TH PERCENT. VALUE (MPN/100ML)	SEGMENT VOLUME (CUBIC METERS)	VOLUME X 90TH PERCENT. VALUE = ACTUAL LOAD	VOLUME X 90TH CRITERIA (49MPN/100ML) = LOAD ALLOCATION	(ALLOW-ABLE LOAD)– (EXISTING LOAD) = LOAD REDUCTION	REQUIRED LOAD REDUCTION IN PERCENT
264.0	5,400,779	1.43E+13	2.65E+12	1.16E+13	81.4%

Table 5-4 90th Percentile Calculations for the Broad and Linkhorn Bay TMDL

AVERAGE90TH PERCENT. VALUE (MPN/100ML)	SEGMENT VOLUME (CUBIC METERS)	VOLUME X 90TH PERCENT. VALUE = ACTUAL LOAD	VOLUME X 90TH CRITERIA (49MPN/100ML) = LOAD ALLOCATION	(ALLOW-ABLE LOAD)– (EXISTING LOAD) = LOAD REDUCTION	REQUIRED LOAD REDUCTION IN PERCENT
90.2	688,472	6.03E+11	3.28E+11	2.75E+11	16.2%

5.2.3. BST Data:

A comparison of the geometric mean data and the 90th percentile data for the last 30 months shows that the 90th percentile data is the more critical condition. In essence the 90th percentile criteria is that criteria most frequently and severely exceeded and it is reductions in these bacterial loadings that will yield water quality improvements which address the water quality standard. Therefore the 90th percentile loading is combined with the results of the BST to allocate source contributions and establish load reduction targets among the various contributing sources.

The BST data determines the percent loading for each of the major source categories and is used to determine where load reductions are needed. Since 12 BST samples were allocated monthly for a period of one year for each TMDL, the percent loading per source were averaged over the 12 month period because there where no seasonal differences between sources. The percent loading by source is multiplied by the 90th percentile load, to determine the load by source. The percent reduction needed to attain the water quality standard or criteria are allocated to each source category. This is shown in Table 5-3 and Table 5-4, and serves to fulfill the TMDL requirements by insuring that the criteria is attained. Additionally it ensures that all sources and loadings are identified and quantified via the BST and mathematical calculations, season variability is addressed, and critical conditions are identified. This data is graphical represented as the annual average BST in Figure 5-1. DEQ is evaluating another methodology to quantify the percent loading per source category. The alternative approach will average the monthly load per source instead of averaging the percent loadings.

5.2.3 Development of Waste Load Allocations

Contributions of pollutants which arrive in a natural system through man-made treatment works such as waste water treatment plants and storm water management systems which are regulated by a VPDES permit constitute a separate load to the system that is considered differently than contributions from wildlife and birds that arrive via more diffuse pathways. This source of loading from anthropogenic sources like these is termed a waste load allocation (WLA) and is the sum of all man-made sources which are regulated under § 402 of the Clean Water Act by the Department of Environmental Quality under the Virginia Pollutant Discharge Elimination System (VPDES). The relationship to the total load allocation (TLA) and load allocation (LA) is shown below:

Total Load Allocation = Waste Load Allocation (WLA) + 5%MOA + Load Allocation (LA)

There are a number of methods to derive the waste load allocation in watersheds. Where a sewage treatment plant, or other permitted treatment plant, is discharging to the system, flow and the pollutant of concern are normally measured at the discharge and regulated by a permit issued by DEQ. In such cases the waste load is known or easily derived. In systems where non-point source contributions arrive through more diffuse sources such as storm water management systems and different BMPs which are normally not monitored for the specific pollutant of concern, determination of a waste load allocation is not as direct and therefore more approximate.

A simple but useful approach in urbanized systems such as the City of Virginia Beach is to adopt an averaging approach based upon land use and known average impervious area by land use type. This is the approach adopted in this TMDL. Table 5-5 shows the land use in the watershed and the percent impervious area by land use type. Averaging the percent impervious area by land use type yields 34% impervious area. This figure is consistent with similarly urbanized areas for which TMDLs have been developed and land use modeled. As an example The Four Mile Run TMDL for the City of Alexandria yielded an average impervious area of 41%. Results of the SWMM model for this area yielded a range of between 35 to 45%. Therefore the value derived for the Lynnhaven, Broad and Linkhorn Bay watershed by simple averaging is consistent with these estimates.

Table 5-5 Average Impervious Area in the Lynnhaven, Broad and Linkhorn Bay Watershed

Land Use Type	Acres	Percent of Land Area	Percent Impervious
Single Family/Duplex	15078	37%	20%
Town House	768	2%	50%
Multi-family	1551	4%	70%
Commercial	1806	4%	70%
Office	652	2%	70%
Industrial	457	1%	65%
Military	2393	6%	50%
Streets	5178	13%	90%
Public/Semi-public	2662	7%	8%
Park	2876	7%	2%
Agriculture-cropland	1717	4%	2%
Agriculture-pasture	248	1%	2%
Marsh/wetland	1711	4%	2%
Approved f/development	6	0%	2%
Undeveloped	3580	9%	2%
Total Area	**40683**	**100%**	
Avg. impervious %			**34%**

Utilizing this method the waste load allocation is arrived at by assigning 34% of the total load allocation calculated under the assumption that this is reflective of the contribution of the impervious area in the watershed. The assumption is that this area is 100% impervious and no bacterial decay, a very conservative assumption. This assertion is undertaken with the understanding that there is no meaningful method to determine specific bacterial loading in a storm water system with 972 major permitted out falls and many more minor out falls distributed throughout a 64 square mile watershed in the absence of data to calibrate the model. Baring the availability of sufficient data from the major out falls to calculate runoff and transport within known BMP service areas of the MS4 watershed this expedient suffices to provide an initial partitioning of the load into waste load allocation (WLA) and Load Allocation (LA).

The 90th percentile water quality standard of 49 MPN/100ml is identified as the initial target for the Lynnhaven Bay and its tributaries, as well as for Broad and Linkhorn Bays. This standard serves as a starting point to the load derivation calculation. Multiplied by the volume of water in the watershed this standard provides the theoretical total load allocation available for all sources in the Lynnhaven watershed. The total available load multiplied by the percent impervious area yields the theoretical waste load allocation for the MS4. Determination of the necessary reduction is obtained by first multiplying the average concentration measured in the system for the 30 Month period by the volume, then calculating the percent difference from the value obtained for the water quality standard. The results of these calculations are summarized for the Lynnhaven Watershed in Table 5-6, and in Table 5-7 for the Broad and Linkhorn Bay Watershed.

Specific calculations for Lynnhaven Bay and tributaries are:

1) Total Load Allocation = (49MPN/100ml) x (basin water volume (cubic meters)) x (conversion factor from cubic meters to milliliters)

2.65 E+12 MPN = (49 MPN/100 ml) x (5,400,779 m^3) x (10000ml/1m^3)

2) Waste Load Allocation (WLA) = Total Load Allocation (TLA) x (Impervious area = 0.34)

9.01 E+11MPN = (2.65 E+11MPN) x (0.34)

3) Load allocation (LA) = Total Load Allocation – Waste Load Allocation (WLA)

1.75 E+12 MPN = 2.65 E+12 MPN – 9.01 E+11 MPN

4) Current Load = Average Concentration (MPN/100ml) x (basin water volume (cubic meters)) * (conversion factor from cubic meters to milliliters)

1.43 E+13 MPN = (264 MPN/100 ml) x (5,400,779 m^3) x (10000ml/1m^3)

Once the volumetric calculation of the total load allocation, WLA and LA have been completed; the partitioning by source category determined through the BST is calculated. This is accomplished by averaging all of the BST values from all stations and all months of the study period, then partitioning the total load, WLA and LA by the appropriate percentage. These are shown for the two watersheds in Tables 5-6 and 5-7.

Table 5-6 REDUCTION BASED UPON 90TH PERCENTILE STANDARD IN LYNNHAVEN BAY

GROWING AREA 70, CLOSURE 25A	BST Result % of total load	Current Actual Load (cfu)*	Waste Load Allocation for MS4 System	Load Allocation for background sources(cfu)	Total New Load Allocation for all sources (cfu)*	Reduction needed
Total	100%	1.43E+13	9.01E+11	1.75E+12	2.65E+12	81.5%
Bird	28.6%	4.09E+12	8.62E+10	1.67E+11	2.54E+11	93.8%
Wildlife	16.8%	2.40E+12	8.16E+11	1.58E+12	2.40E+12	0%
Human	24.8%	3.55E+12	0.00E+00	0.00E+00	0.00E+00	100%
Pets	14.4%	2.06E+12	0.00E+00	0.00E+00	0.00E+00	100%
Livestock	16.8%	2.40E+12	0.00E+00	0.00E+00	0.00E+00	100%

Table 5-7 REDUCTION BASED UPON 90TH PERCENTILE STANDARD IN BROAD AND LINKHORN BAYS

GROWING AREA 71, CLOSURE 25B	BST Result % of total load	Actual Load (cfu)*	Waste Load Allocation	Load Allocation (cfu)*	Total Load Allocation (cfu)*	Reduction needed
Total	100%	3.28E+11	9.35E+10	1.82E+11	2.75E+11	16.2%
Bird	28.6%	9.38E+10	3.19E+10	6.19E+10	9.38E+10	0%
Wildlife	16.8%	5.51E+10	1.87E+10	3.64E+10	5.51E+10	0%
Human	24.8%	8.13E+10	1.38E+10	2.68E+10	4.07E+10	50%
Pets	14.4%	4.72E+10	1.60E+10	3.12E+10	4.72E+10	0%
Livestock	16.8%	5.51E+10	1.87E+10	3.64E+10	5.51E+10	0%

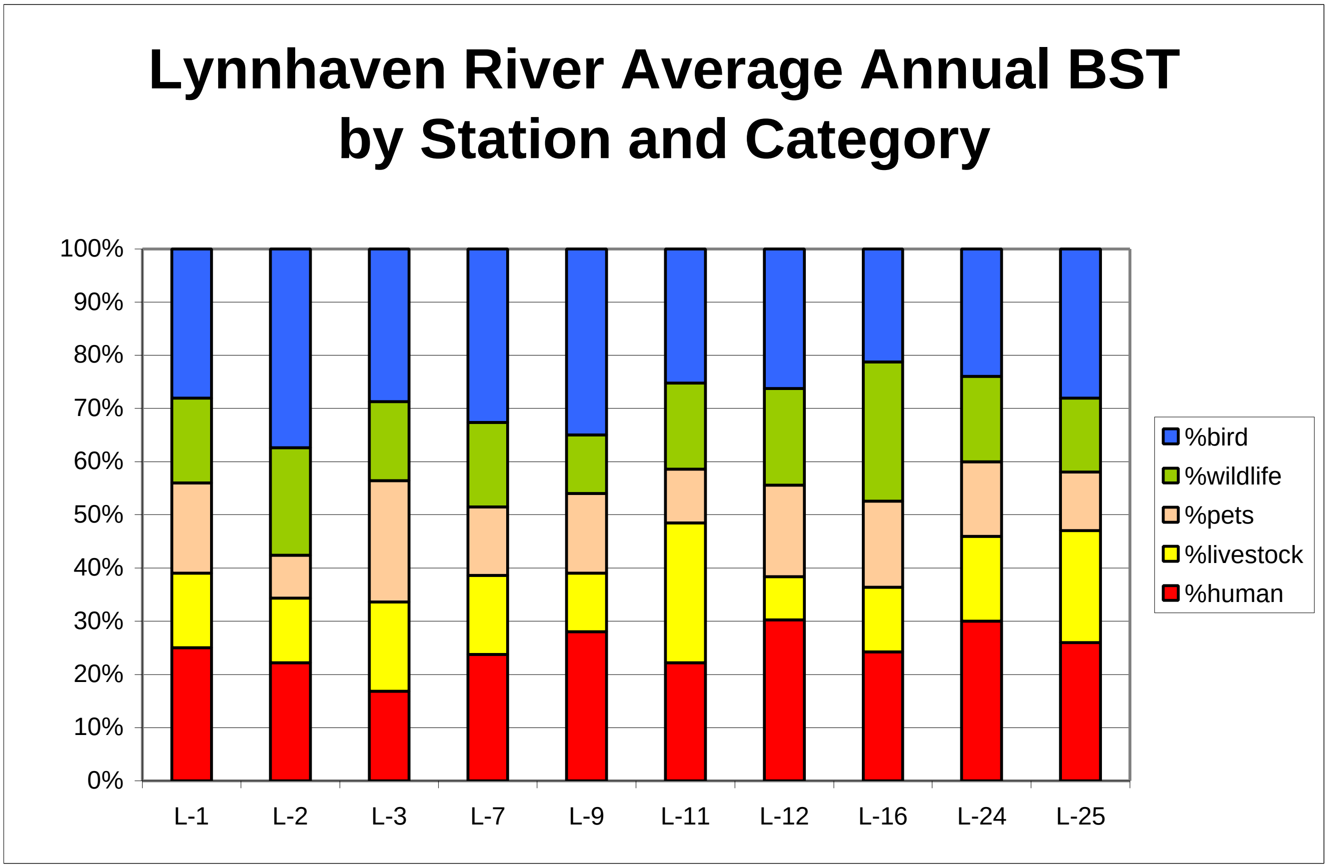
*** Total Load Allocation = waste load allocation (WLA) + MOS + Load Allocation (LA)**

5.3. Consideration of Critical Conditions

EPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the Lynnhaven Bay and its tributaries are protected during times when they are most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and which may help in identifying actions that may have to be undertaken to meet water quality standards. The sources of bacteria for the Lynnhaven River estuary are the result of a mixture of dry and wet weather driven sources. TMDL development utilized the volumetric load determination approach the results of which are summarized in Table 5.8. Because of the conservative assumptions made in the volumetric approach, addressing the critical conditions for this watershed is implicit in the TMDL development. There was very little seasonality in BST results and in the measured concentrations of fecal coliforms. This resulted in an averaging approach to load allocation in the watershed. A margin of safety is also implicit in this approach as it is developed to target the highest level of excedence of the water quality standard, assumes no flushing, and has a conservative assimilation capacity.

Figure 5-1



	% Bird	%Human	% Livestock	% Pets	% Wildlife
BL-1	28	25	14	17	16
L-2	37	22	12	8	20
L-3	29	17	17	23	15
L-7	33	24	15	13	16
L-9	35	28	11	15	11
L-11	25	22	26	10	16
L-12	26	30	8	17	18
L-16	21	24	12	16	26
L-24	24	30	16	14	16
L-25	28	26	21	11	14
Cumulative Average	**28.6**	**24.8**	**15.2**	**14.4**	**16.8**

Table 5.8 TMDL Summary for Two Growing Areas: 1) Lynnhaven Bay, and 2) Broad and Linkhorn Bay Watersheds

Water Body / Closure ID	Pollutant Identified	TMDL c.f.u.*	Waste Load Allocation c.f.u.*	Load Allocation c.f.u.*	Margin of Safety
1) Lynnhaven Bay	**Fecal Coliform**	**2.65E+12**	**9.01E+11**	**1.75 E+12**	**Implicit**
2) Broad and Linkhorn Bay	**Fecal Coliform**	**2.75E+11**	**9.35E+10**	**1.82E+11**	**Implicit**

*** c.f.u. = colony forming units of bacteria (CFU and MPN are equivalent measures**)

A margin of safety (MOS) included in the TMDL development process to account for any uncertainty on loadings and the fate of fecal coliform bacteria in the Lynnhaven, Broad and Linkhorn Bays. There are two basic approaches for incorporating an MOS:

- The MOS is implicitly incorporated using conservative assumptions to develop allocations
- The MOS is explicitly specified as a portion of the Total TMDL and the remainder is used for allocations

In this report the TMDL margin of safety (MOS) is implicit in the conservative assumptions regarding impervious area and by adopting an a watershed approach which seeks to eliminate 100% of the human derived fecal component even though less than 30% reduction is required to meet bacterial TMDL targets. Human derived fecal coliforms are a serious concern in the estuarine environment and discharge of human waste is precluded by state and federal law.

5.4. Consideration of Seasonal Variations

Seasonal variations involve changes in surface runoff, stream flow, and water quality as a result of hydrologic and climatological patterns. The volumetric approach examines the pattern of water quality through a combination of the BST as compared to recent rainfall events in order to consider seasonal variations. This permits consideration of temporal variability in fecal coliform sources, such as migrating duck and goose populations, within the watershed. No seasonal variations were noted in these data for the special study period.

6.0 TMDL Implementation

The goal of the TMDL program is to establish a three-step process that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the bacteria impairments on the Lynnhaven, Broad and Linkhorn bays. The second step is to develop a TMDL implementation plan. The final step is to implement the plan, and to monitor water quality to determine if standards are being attained.

Upon approval of a TMDL by EPA, measures must be taken to reduce pollution levels in the water body. These measures, which can include the use of better treatment technology and the installation or retro-fitting best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the recent "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.state.va.us/tmdl/implans/ipguide.pdf With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

6.1 Staged Implementation

In urbanized areas focus naturally shifts to human sources of pollution and measures to address them. As with most urban areas the City of Virginia Beach has a significant number of potential sources of bacterial loading and has over the past several years reported numerous discharges from the sewer system network which serves the City's residents and businesses. Further the shoreline survey indicates that recreational boating activity may be a significant contributing source of human waste water bacterial loading. In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice is livestock exclusion from water bodies. This has been shown to be very effective in lowering bacteria concentrations in water bodies, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems. The City of Virginia Beach operates such a replacement program and is actively pursuing providing municipal sewer to areas currently served by septic systems.

In urban areas, reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. The City of Virginia Beach has an active program to line all existing sewered areas and prevent exfiltration of waste into adjacent systems. Other BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, reducing boating related discharges and improved street cleaning.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;

4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. While specific goals for BMP implementation will be established as part of the implementation plan development, the following stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

6.2. Stage 1 scenarios

The goal of the stage 1 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the geometric mean or 90th percentile criterion (14 MPN/100ml and 49 MPN/100 ml respectively) are not exceeded. The stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios. A margin of safety was not used in determining the stage 1 scenarios.

6.3 Link to ongoing Restoration Efforts by the City of Virginia Beach

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. These efforts have been in existence since shortly after the City was formed in 1963 and include the following:

1. sanitary sewer line rehabilitation/replacement;
2. extending sanitary sewer systems to currently un-sewered areas;
3. a program of mandatory sewer connections; and
4. upgrading and rehabilitating sewage pump stations.

These sanitary sewer system improvements, including those illustrated in Figures 4-3 and 4-4, were accomplished with the expenditure of approximately $100,000,000 adjusted to year 2002 dollars, in the Lynnhaven Watershed alone.

Other ongoing City activities in this watershed linked to watershed restoration include:

1. oyster habitat restoration;
2. riparian buffer restoration;
3. Chesapeake Bay Program septic tank pump out and inventory system;
4. maintenance of oil water separators;
5. street sweeping;
6. drainage structure maintenance;
7. BMP inspections (ponds, dry ponds, infiltration ponds, storm water treatment devices) of public and private BMP’s;
8. public education of homeowners and homeowners associations, Boy Scouts, Clean the Bay Day, Earth Day, including distribution of educational materials;

9. drainage ditch bank stabilization;
10. Adopt a Waterway Program;
11. response to spills and other environmental inquiries and concerns;
12. dredged John B Dey Pond for water quantity and quality improvements;
13. slip lining drainage pipes to eliminate cave-ins and associated movement of sediment into downstream waters;
14. hydrographic surveys of storm water ponds;
15. enforcement of storm sewer discharge ordinance;
16. recycling program;
17. dry weather field screening; and
18. construction of water quality ponds.

6.4 Reasonable Assurance for Implementation

6.4.1 Follow-Up Monitoring

VDH-DSS will continue monitoring all stations within the Lynnhaven, Broad and Linkhorn bays in accordance with its ambient monitoring program to evaluate reductions in fecal bacteria counts and the effectiveness of TMDL implementation in attainment of water quality standards. Additionally the City of Virginia Beach Department of Public Works is exploring expanding its dry weather field screening to include monitoring for optical brighteners, and possibly for fecal coliform bacteria or enterococci.

6.4.2 Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and waste load allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.
Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

6.4.3. Stormwater Permits

It is the intention of the Commonwealth that the TMDL will be implemented using existing regulations and programs. One of these regulations is the Virginia Pollutant Discharge Elimination System (VPDES) Permit Regulation (9 VAC 25-31-10 et seq.). Section 9 VAC 25-31-120 describes the requirements for storm water discharges. Also, federal regulations state in 40 CFR §122.44(k) that NPDES permit conditions may consist of "Best management practices to control or abate the discharge of pollutants when: (2) Numeric effluent limitations are infeasible,…".

All of the Lynnhaven, Broad and Linkhorn Bay watershed is covered by Phase I VPDES permits VA0088676 for the municipal separate storm sewer systems (MS-4s) owned by the City of Virginia Beach. These permits were issued on January 6, 1996. The effective date of coverage is March 8, 2006. The permits state, under Part II.A., that the "permittee" must develop, implement, and enforce a storm water management program designed to reduce the discharge of pollutants from the MS4 to the maximum extent practicable (MEP), to protect water quality, and to satisfy the appropriate water quality requirements of the Clean Water Act and the State Water Control Law." The permit also contains a TMDL clause that states: "If a TMDL is approved for any water body into which the small MS4 discharges, the Board will review the TMDL to determine whether the TMDL includes requirements for control of storm water discharges. If discharges from the MS4 are not meeting the TMDL allocations, the Board will notify the permittee of that finding and may require that the Storm Water Management Program required in Part II be modified to implement the TMDL within a timeframe consistent with the TMDL."

For MS4/VPDES general permits, DEQ expects revisions to the permittee's Storm Water Pollution Prevention Plans to specifically address the TMDL pollutants of concern. DEQ anticipates that BMP effectiveness would be determined through ambient in-stream monitoring. This is in accordance with recent EPA guidance (EPA Memorandum on TMDLs and Stormwater Permits, dated November 22, 2002). If future monitoring indicates no improvement in water body water quality, the permit could require the MS4 to expand or better tailor its BMPs to achieve the TMDL reductions. However, only failing to implement the required BMPs would be considered a violation of the permit. DEQ acknowledges that it may not be possible to meet the existing water quality standard because of the wildlife issue associated with a number of bacteria TMDLs (see section 7.4.5 below). At some future. time, it may therefore become necessary to investigate the water body's use designation and adjust the water quality criteria through a Use Attainability Analysis. Any changes to the TMDL resulting from water quality standards change on the Lynnhaven, Broad or Linkhorn would be reflected in the permittee's Storm Water Pollution Prevention Plan required by the MS4/VPDES permit. Additional information on Virginia's Storm Water Phase 1 program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.deq.state.va.us/water/bmps.html.

6.4.4 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for Virginia's Non-point Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

6.4.5 Addressing Wildlife Contributions

In some water bodies for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the water body will not attain standards under all flow regimes at all times. As is the case for the Lynnhaven, Broad and Linkhorn Bays, these water bodies may not be able to attain standards without some reduction in wildlife load. **Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards.** While managing over populations of wildlife remains as an limited option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

To address this issue, Virginia has proposed (during its recent triennial water quality standards review) a new "secondary contact" category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for "secondary contact recreation" which means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)". These new criteria will become effective pending EPA approval and can be found at http://www.deq.state.va.us/wqs/rule.html.

In order for the new criteria to apply to a specific water body segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of bacterial contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for non-point source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at http://www.deq.state.va.us/wqs/WQS03AUG.pdf
Based on the above, EPA and Virginia have developed a process to address the wildlife issue. First in this process is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of over populations. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in section 6.1 above. DEQ will re-assess water quality in the water body during and subsequent to the

implementation of the stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, a UAA may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the UAA phase because the water quality standard excedences attributed to wildlife in the model may have been very small and infrequent and within the margin of error.

7.0. Public Participation

The development of the Lynnhaven Bay, Broad Bay and Linkhorn Bay TMDL would not have been possible without public participation. Several stakeholder meetings were held at the City of Virginia Beach, Department of Public Works offices from May through November of 2003 to discuss the process for TMDL development and the source assessment results. City of Virginia Beach personnel and state agency personnel representing state and local government attended each meeting.

The formal notice of the public meeting was printed in the Virginia Register on November 17, 2003. Notices were also published in the local area newspaper. The public meeting was held at the Princess Anne High School on December 2, 2003. Members of the Virginia Beach Planning Board, Departments of Public, Works, Planning and Utilities, concerned citizens, and affected state agencies attended. A formal presentation of the results contained in this TMDL report was made by DEQ staff and public comment solicited. The City of Virginia Beach also made a presentation on their ongoing efforts to correct sewer system deficiencies. A copy of the TMDL presentation was made available at the meeting and on the DEQ web site. There followed a 30-day public comment period and no written comments were received.

Generally, the public comment garnered at the meeting focused on the issue of how the implementation of the TMDL could be funded and what effect the TMDL might have on the City's efforts to improve the water quality in the Lynnhaven, Broad and Linkhorn Bays. Secondary issues, such as potential bacterial sources, changes in use designation, and concerns over the regulatory consequences of not meeting the TMDL load allocation were also raised. Written comments were received from the Hampton Roads Planning District Commission, the Virginia Beach Department of Public Utilities and the Virginia Beach City Manager.

References

City of Virginia Beach, Southeast Regional Climate center, sercc@dnr.state.sc.us

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Virginia Department of Health, Shoreline Bacteria Monitoring Data for the Lynnhaven Bay, Broad and Linkhorn Bays. Available from the Virginia Department of Health, Division of Shellfish Sanitation. Richmond, Virginia.

Virginia National Land Cover Data (NLCD) Version 05-27-99

GLOSSARY

Note: All entries in italics are taken from USEPA (1998).

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.
Allocations. That portion of receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)
Ambient water quality. Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.
Anthropogenic. Pertains to the [environmental] influence of human activities.
Bacteria. Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.
Bacterial source tracking (BST). A collection of scientific methods used to track sources of fecal contamination.
Best management practices (BMPs). Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.
Clean Water Act (CWA). The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is section 303(d), which establishes the TMDL program.
Concentration. Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).
Contamination. The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.
Cost-share program. A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).
Critical condition. The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.
Designated uses. Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.
Domestic wastewater. Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.
Drainage basin. A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.

Existing use. Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).
Fecal Coliform. Indicator organisms (organisms indicating presence of pathogens) associated with the digestive tract.
Geometric mean. A measure of the central tendency of a data set that minimizes the effects of extreme values.
GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)
Infiltration capacity. The capacity of a soil to allow water to infiltrate into or through it during a storm.
Interflow. Runoff that travels just below the surface of the soil.
Loading, Load, Loading rate. The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.
Load allocation (LA). The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).
Loading capacity (LC). The greatest amount of loading a water body can receive without violating water quality standards.
Margin of safety (MOS). A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving water body (CWA section 303(d)(1)©). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).
Mean. The sum of the values in a data set divided by the number of values in the data set.
Monitoring. Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.
Narrative criteria. Non-quantitative guidelines that describe the desired water quality goals.
Nonpoint source. Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.
Numeric targets. A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.
Point source. Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water waterbody or river.
Pollutant. Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).

Pollution. Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Privately owned treatment works. Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.

Public comment period. The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a Federal Register notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).

Publicly owned treatment works (POTW). Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.

Raw sewage. Untreated municipal sewage.

Receiving waters. Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.

Riparian areas. Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.

Riparian zone. The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.

Runoff. That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Septic system. An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.

Sewer. A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.

Slope. The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).

Stakeholder. Any person with a vested interest in the TMDL development.

Surface area. The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.

Surface runoff. Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.

Surface water. All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.

Topography. The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.
Total Maximum Daily Load (TMDL). The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.
VADEQ. Virginia Department of Environmental Quality.
VDH. Virginia Department of Health.
Virginia Pollutant Discharge Elimination System (NPDES). The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.
Wasteload allocation (WLA). The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).
Wastewater. Usually refers to effluent from a sewage treatment plant. See also **Domestic wastewater**.
Wastewater treatment. Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.
Water quality. The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.
Water quality criteria. Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.
Water quality standard. Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.
Watershed. A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.
WQIA. Water Quality Improvement Act.

APPENDIX A

1) Sanitary Shorline Survey for the Lynnhaven River Watershed

2) Shellfish Area Closure Notification 25

Department of Health

\NNE PETERSON, M.D., M.P.H.
\TE HEALTH COMMISSIONER

P O BOX 2448
RICHMOND, VA 23218

TDD 1-800•828-1120 ',

Lynnhaven Bay
Shoreline Sanitary Survey
City of Virginia Beach

Date: October 12, 2000
Survey Period: May 18, 2000 to June 7, 2000
Total Number of Properties Surveyed: 360
Surveyed by: H. R. Barker, Jr., T. D. Fearington, H. J. Isiminger, and J. E. Merritt

SECTION A: GENERAL

This survey area extends ,from Reference Point 71 on the western bank of Lynnhaven Inlet at the Lesner Bridge to Reference Point 72 at the bridge near the end of Inlet Road at the southern mouth of Long Creek, including the Lynnhaven River shoreline between these two points, Crab Creek, Pleasure House Creek,. Western Branch of the Lynnhaven River [Bayville Creek, Thoroughgood Cove, Witch Duck Bay, Thurston Branch (Thalia Creek), Buchanan Creek, Hebden Cove], Lynnhaven Bay [Keeling Cove, Dix Creek, Poorhouse Cove], Eastern Branch of the Lynnhaven River [Pinetree Branch, London Bridge Creek, Wolfsnare Creek,. Brown Cove, Great Neck Lake], Brock Cove, Keeling Drain, and all of their tributaries. The survey boundary has been revised. See map for current boundary.
The topography of the area varies from 5' or less along the shoreline to a maximum of 25' near the outer edge of the survey boundary. The population density is highly concentrated throughout most of the area that is primarily sewered. The economy is based on service-oriented businesses, tourism, and the nearby military installations.
Meteorological data indicated that 5.10" or rain fell May 18-31 and .63" June 1-7 for a total rainfall of 5.73" for the survey period.

The previous survey noted a few significant properties inside the Oceana Naval Air Station, which is now located outside the current survey boundary. The two solid waste dumpsites (property #699 and property #702) had a status change. Property #699, which was used for domestic refuse and garbage has been closed. The site is routinely monitored for methane and the ground water is periodically tested. Property #702, which was used for road debris is not of significance and does not require a permit from the Department of Environmental Quality (DEQ). Oceana. Naval Air Station continues to operate under VPDES Permit #VA0005266 for industrial waste property #A.

Development primarily consists of suburban residential properties with little room remaining for new construction. Commercial development is limited to the major thoroughfares, all of which are sewered. The City of Virginia Beach is installing sanitary sewerage facilities at such a rapid pace that the number of onsite septic system properties located within the boundary has been greatly reduced. The only significant portion of the survey area that is not sewered is located in the western half of the City of Virginia Beach and is known as Little Neck. There are no direct sewage treatment discharges located within the area. All sewered areas of the survey are either connected to the ChesapeakeElizabeth sewage treatment works (STW), which discharges into the Chesapeake Bay (growing area #68); or the Atlantic STW, which discharges into the Atlantic Ocean (growing area #73).

The current restriction on shellfish harvesting is Condemned Shellfish Area #25, Lynnhaven, Broad and Linkhorn Bays, revised 10 April 1998. A copy of the current condemnation notice and map is attached to the back of this report.

Information in this report is gathered by and primarily for the use of the Division of Shellfish Sanitation, Virginia Department of Health, in order to fulfill its responsibilities of shellfish growing area supervision and classification. However, the data is made available to various agencies participating in shellfish program coordinated activities and other interested parties.

Report copies are provided to the local health department for possible corrective action at those properties listed on the summary page in Section B.3. and DEQ for possible action at the property listed on the summary page in Section C.1.

This report lists only those properties that have a sanitary deficiency or other environmental significance. *"DIRECT"* indicates that the significant activity or deficiency has a direct impact on shellfish waters. Individual field forms with full information on properties listed in this report are on file in the Richmond Office of the Division of Shellfish Sanitation and are available for reference until superseded by a subsequent resurvey of the area.

SECTION B: SEWAGE POLLUTION SOURCES

SEWAGE TREATMENT WORKS

-None

ONSITE SEWAGE DEFICIENCIES

-None

POTENTIAL POLLUTION

1. [redacted] Dwelling- brown wooden beam and stucco 2'/z story Tudor with brown trim. 4 persons. Housekeeper stated that the toilets flush slowly and that a plumber was contacted. No evidence of discharge at time of inspection.

2. [redacted]. Dwelling- white brick 2 story with sea foam shutters. 5 persons. Owner stated that during heavy rains the septic system backs up and the washing machine cannot be used. Also noted during these conditions are odors over the septic tank and drainfield. No evidence of discharge at time of inspection.

3. [redacted]. Dwelling- brick 1 story with black trim and shutters. 2 persons. Owner stated that following a heavy rain there is a septic odor over the drainfield. No evidence of discharge at time of inspection.

4. [redacted]. Dwelling- brick 2 story Colonial with taupe trim and green shutters. 3 persons. Owner stated that there has been prior septic system failures. He has also noted the presence of odors and excessive moisture in the vicinity of the drainfield following a heavy rainfall. No evidence of discharge at time of inspection.

5. [redacted]. Dwelling- natural stained frame 2 story. 3 persons. Owner stated that the septic system failed 2 weeks prior to this inspection. The septic tank has been pumped. No evidence of discharge at time of inspection.

6. [redacted]. Dwelling- brick 1 story with white trim and shutters. 2 persons. Owner stated that during a heavy rainfall the washer cannot be used and that there is a septic odor present. No evidence of discharge at time of inspection.

SECTION C: NON-SEWAGE WASTE SITES
INDUSTRIAL WASTES

A. *DIRECT -* [redacted]. Military installation- naval air station. 10,000 troops and civilian employees. Storm water runoff from aircraft runways, aircraft fueling and parking areas, fuel storage areas, various cooling blow downs, and various training areas discharges into London Bridge Creek. Has VPDES Permit #VA0005266 from Department of Environmental Quality, Water Regional Office.

SOLID WASTE DUMPSITES

-None

SECTION D: BOATING ACTIVITY

MARINAS

-None

OTHER PLACES WHERE BOATS ARE MOORED

-None

UNDER SURVEILLANCE

-None

SECTION E: CONTRIBUTES ANIMAL POLLUTION

-None-

SUMMARY

Area #70
Lynnhaven Bay
October 12, 2000

SECTION B: SEWAGE POLLUTION SOURCES

1. SEWAGE TREATMENT WORKS

0 - DIRECT - None
Q -INDIRECT - None
0 - B.1. TOTAL

2. ON-SITE SEWAGE DEFICIENCIES

0 - CONTRIBUTES POLLUTION, DIRECT - None
0 - CONTRIBUTES POLLUTION, INDIRECT - None

0 - CP (Kitchen or Laundry Wastes), DIRECT - None
0 - CP (Kitchen or Laundry Wastes), INDIRECT - None

0 - NO FACILITIES, DIRECT - None
Q - NO FACILITIES, INDIRECT - None
0 - B.2. TOTAL

3. **POTENTIAL POLLUTION**

6 - POTENTIAL POLLUTION - #1, 2, 3, 4, 5, **6**

SECTION C: NON-SEWAGE WASTE SITES

1. INDUSTRIAL WASTE SITES

1 - DIRECT - A
Q -INDIRECT - None
1 - C.1. TOTAL

2. SOLID WASTE DUMPSITES

0 - DIRECT - None Q
-INDIRECT - None 0
-C.2. TOTAL

SECTION D: BOATING ACTIVITY

0 - MARINAS - None 0 - OTHER PLACES WHERE BOATS ARE
MOORED - None Q - UNDER SURVEILLANCE - None 0 - D. TOTAL

SECTION E: CONTRIBUTES ANIMAL POLLUTION

0 - DIRECT - None Q
-INDIRECT - None 0 -E.
TOTAL

COMMONWEALTH of VIRGINIA

Department of Health
Office of Water Programs
Division of Shellfish Sanitation
1500 East Main Street, Suite 109
Richmond, Virginia 23219-3635

RANDOLPH L. GORDON, M.D., M.P.H.
COMMISSIONER

PHONE (804) 786-7937
FAX (804) 786-5567

NOTICE AND DESCRIPTION OF SHELLFISH AREA CONDEMNATION NUMBER 25, LYNNHAVEN, BROAD AND LINKHORN BAYS

EFFECTIVE 10 APRIL 1998

Pursuant to Title 28.2, Chapter 8, §§28.2-803 through 28.2-808, §32.1-20, and §9-6.14:4.1, B.16 of the *Code of Virginia:*

1. The "Notice and Description of Shellfish Area Condemnation Number 25, Lynnhaven, Broad and Linkhorn Bays and Tributaries," effective 11 April 1996, is canceled effective 10 April 1998.

2. Condemned Shellfish Area Number 25, Lynnhaven, Broad and Linkhorn Bays, is established, effective 10 April 1998. It shall be unlawful for any person, firm, or corporation to take shellfish from area #25 for any purpose, except by permit granted by the Marine Resources Commission, as provided in Section 28.2-810 of the *Code of Virginia.* The boundaries of the area are shown on map titled "Lynnhaven, Broad and Linkhorn Bays, Condemned Shellfish Area Number 25, 10 April 1998" which is part of this notice.

3. The Department of Health will receive, consider and respond to petitions by any interested person at any time with respect to reconsideration or revision of this order.

BOUNDARIES OF CONDEMNED AREA NUMBER 25

A. The condemned area shall include all of Lynnhaven Bay, Lynnhaven River and their tributaries upstream of the upstream side of the Lesner Bridge and west of the western boundary of part B, Long Creek and Long Creek Canal.

B. This area includes Long Creek, canal and tributaries enclosed by a line beginning at the prominent point of land south of the east end of the Lesner Bridge; thence southeasterly along the western shores of four small islands to the westernmost point of the shore; thence east and north around the shore to the south shore of Long Creek; thence easterly along the south shore of Long Creek and Broad Bay to Virginia Marine Resources Commission survey marker "A"; thence due north to the opposite shore; thence easterly along the shoreline to the easternmost projection of Carter Point; thence due east to the opposing shore; thence north and west along the north shore to the point of beginning.

C. The condemned area shall include all of Dey Cove and Mill Dam Creek and their tributaries upstream of a line across the common mouth at its most constricted point.

D.

D. The condemned area shall include all of Linkhorn Bay and its tributaries upstream of a line across The Narrows at its most constricted point..

Recommended by:

Director, Division of Shellfish Sanitation

Ordered by State Health Commissioner Date

**SIGNED PURSUANT TO
AUTHORITY VESTED iN
DEPUTY HEALTH COMMISSIONER
BY §2.1-20-01:2: CODE OF VA**

Virginia Department of Health, Division of Shellfish Sanitation Printed on 01/18/01

Area 70: LYNNHAVEN BAY

Bacteriological Data - Fecal Coliforms

All Tides Data; Collected Under Systematic Random Sampling; Catastrophic Event Data Excluded

tation	Class	First Date	Last Date	# of Samples	Geo Mean	Est. 90th Percentile	Meets NSSP Std
1	R	05/28/1998	12/27/2000	30	13.8	97.0	No
2	R	05/28/1998	12/27/2000	30	21.2	173.5	No
2Z	R	05/28/1998	12/27/2000	30	15.7	151.4	No
3	R	05/28/1998	12/27/2000	30	25.8	352.4	No
4	R	05/28/1998	12/27/2000	30	33.9	300.6	No
4.3	R	05/28/1998	12/27/2000	30	40.0	313.5	No
4.9	R	04/29/1998	12/27/2000	30	19.7	237.9	No
5	R	12/19/1997	12/27/2000	30	23.7	221.2	No
7	R	05/28/1998	12/27/2000	30	28.3	295.2	No
8	R	05/28/1998	12/27/2000	30	39.6	535.4	No
9	R	05/28/1998	12/27/2000	30	54.3	491.7	No
10	R	05/28/1998	12/27/2000	30	48.9	592.1	No
11	R	05/28/1998	12/27/2000	30	36.5	274.4	No
12	R	05/28/1998	12/27/2000	30	62.0	888.3	No
15	R	05/28/1998	12/27/2000	30	16.5	146.2	No
16	R	05/28/1998	12/27/2000	30	21.5	248.8	No
17	R	05/28/1998	12/27/2000	30	28.5	361.9	No
18	R	05/28/1998	12/27/2000	30	27.1	452.8	No
24	R	05/28/1998	12/27/2000	30	51.7	654:7	No
25	R	05/28/1998	12/27/2000	30	70.6	" 1052.2	No

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Virginia Department of Health, Division of Shellfish Sanitation

Printed on1/18/

Area 70: LYNNHAVEN BAY - Bacteriological Data - Fecal Coliform MPN's

ass	12/27/00	11/29/00	10/30/00	09/27/00	08/29/00	07/27/00	06/28/00	05/30/00	04/26/00	03/29/00	02/28/0(	'27/99	09/15/99
R	3.6	3.6	2.9	240.0	2.9	43.0	93.0	150.0	43.0	93.0	3.6	43.0	2.9
R	23.0	3.6	3.6	23.0	3.6	23.0	1200.0	23.0	93.0	23.0	23.0	460.0	3.6
R	7.2	3.6	2.9	93.0	2.9	93.0	460.0	240.0	23.0	23.0	3.6	460.0	3.6
R	3.6	9.1	43.0	150.0	9.1	1100.0	210.0	1100.0	23.0	14.0	7.3	460.0	2.9
R	3.6	21.0	43.0	93.0	23.0	43.0	1100.0	460.0	21.0	9.1	9.1	460.0	7.3
R	3.6	3.6	3.6	93.0	43.0	93.0	460.0	1200.0	75.0	240.0	15.0	23.0	23.0
R	3.6	2.9	23.0	43.0	23.0	75.0	0.0	1200.0	43.0	9.1	3.6	1100.0	3.6
R	2.9	3.6	9.1	23.0	9.1	43.0	0.0	1200.0	240.0	9.1	9.1	0.0	15.0
R	2.9	23.0	3.6	210.0	43.0	93.0	1100.0	1100.0	39.0	43.0	3.6	1200.0	9.1
R	3.6	9.1	9.1	43.0	21.0	1100.0	1200.0	1200.0	43.0	240.0	23.0	1100.0	3.6
R	15.0	15.0	3.6	43.0	43.0	460.0	1200.0	1200.0	75.0	75.0	15.0	1200.0	23.0
R	3.6	9.1	7.3	150.0	93.0	1100.0	1100.0	1100.0	23.0	23.0	23.0	1100.0	2.9
R	7.2	21.0	23.0	150.0	43.0	150.0	460.0	460.0	43.0	23.0	39.0	150.0	3.6
R	2.9	7.2	9.1	93.0	23.0	1100.0	1200.0	1200.0	210.0	93.0	150.0	1100.0	3.0
R	9.1	3.6	3.6	43.0	2.9	240.0	240.0	460.0	23.0	15.0	3.6	240.0	43.0
R	43.0	2.9	23.0	93.0	7.3	93.0	460.0	1100.0	75.0	23.0	9.1	1100.0	3.6
R	9.1	9.1	3.0	240.0	15.0	93.0	1200.0	1100.0	9.1	23.0	23.0	1200.0	3.6
R	15.0	15.0	9.1	93.0	23.0	1100.0	1200.0	1100.0	15.0	3.6	3.0	460.0	3.6
R	150.0	9.1	9.1	1200.0	3.6	150.0	1200.0	1200.0	93.0	15.0	39.0	1200.0	15.0
R	3.6	3.6	9.1	1100.0	240.0	290.0	1200.0	1200.0	460.0	93.0	23.0	1200.0	2:9

Virginia Department of Health, Division of Shellfish Sanitation

Printed on1/18/

Area 70: LYNNHAVEN BAY - Bacteriological Data - Fecal Coliform MPN's

ıss	06/24/99	05/26/99	04/28/99	03/29/99	02/22/99	01 /27/99	12/21/98	11/24/98	10/28/98	09/28/98	08/31/9	5/28/98	04/29/98
:	2.9	3.6	3.6	3.6	9.1	23.0	43.0	2.9	43.0	9.1	460.0	9.1	23.0
:	23.0	2.9	23.0	15.0	23.0	3.6	93.0	3.0	23.0	23.0	1200.0	43.0	93.0
:	9.1	9.1	9.1	3.6	9.1	240.0	9.1	3.6	9.1	3.6	1200.0	23.0	9.1
:	3.6	2.9	9.1	3.6	39.0	460.0	3.6	3.6	9.1	9.1	1100.0	3.6	93.0
:	9.1	3.6	9.1	9.1	93.0	240.0	93.0	3.6	3.6	23.0	1200.0	23.0	240.0
:	23.0	43.0	43.0	2.9	23.0	93.0	240.0	3.6	240.0	9.1	240.0	7.3	210.0
:	3.6	3.6	2.9	15.0	2.9	460.0	9.1	23.0	9.1	3.6	1200.0	3.6	240.0
:	3.6	43.0	9.1	0.0	23.0	0.0	15.0	9.1	43.0	3.6	1200.0	0.0	460.0
:	3.6	9.1	15.0	23.0	43.0	39.0	3.6	9.1	9.1	23.0	1200.0	23.0	93.0
:	2.9	23.0	9.1	23.0	39.0	93.0	9.1	9.1	43.0	2.9	1200.0	15.0	1100.0
:	43.0	9.1	9.1	93.0	3.6	93.0	23.0	14.0	23.0	23.0	1200.0	23.0	1100.0
:	9.1	9.1	23.0	93.0	9.1	460.0	9.1	15.0	43.0	9.1	1200.0	93.0	1100.0
:	2.9	39.0	23.0	15.0	9.1	43.0	15.0	14.0	23.0	2.9	1200.0	43.0	1200.0
:	39.0	23.0	23.0	460.0	9.1	1100.0	23.0	2.9	9.1	3.6	1200.0	23.0	1200.0
:	3.6	3.6	9.1	43.0	9.1	240.0	9.1	2.9	3.6	9.1	460.0	3.6	23.0
:	3.6	15.0	3.6	43.0	23.0	240.0	9.1	3.6	3.6	3.6	1100.0	23.0	9.1
:	2.9	23.0	3.6	21.0	23.0	240.0	23.0	9.1	3.6	3.6	1200.0	23.0	460.0
:	2.9	3.6	3.6	3.6	460.0	150.0	3.6	3.6	15.0	9.1	1200.0	9.1	1200.0
:	9.1	43.0	23.0	23.0	23.0	240.0	3.6	3.6	15.0	7.3	1200.0	15.0	1100.0
:	23.0	75.0	23.0	240.0	9.1	1100.0	9.1	2.9	9.1	15.0	1200.0	43.0	1200.0

Virginia Department of Health, Division of Shellfish Sanitation

Area 70: LYNNHAVEN BAY - Hydrographic and Bacteriological Data

12/27/00 11/29/00 10/30/00 09/27/00 08/29/00 07/27/00 06/28/00 05/30/00 04/26/00 03/29/00 02128/00 01/31.
27/99 09/15/99

0.00	0.00	0.00	0.47	0.66	0.28	0.00	0.27	0.01	0.44	0.00	0.00	0.00	0.00
0.00	0.02	0.00	0.48	0.67	2.94	0.00	1.24	0.01	0.46	0.00	0.00	0.00	0.00
0.00	0.69	0.00	1.54	2.00	3.00	2.78	1.24	0.02	0.46	0.00	0.00	0.00	0.00
0.00	0.69	0.00	1.57	2.15	3.02	2.78	1.34	0.03	0.46	0.00	0.00	0.00	0.00
0.00	0.69	0.00	1.57	2.16	3.02	2.80	1.34	0.03	0.46	0.00	0.91	0.16	0.03
0.00	0.69	0.00	1.57	2.16	3.23	2.80	1.34	0.09	0.57	0.00	1.57	0.19	0.67
0.02	0.69	0.00	1.57	2.16	4.22	2.81	2.02	1.08	1.13	0.00	1.89	0.22	0.67

12/25/00 11/27/00 10/28/00 09/25/00 08/27/00 07/25/00 06/26/00 05/28/00 04/24/00 03/27/00 02/26/00 0
9 09/13/99

0.00 0.00 0.00 0.47 0.66 0.28 0.00 0.27 0.01 0.44 0.00 0.00 0.00 0.00

12/24/00 11/26/00 10/27/00 09/24/0008/26/00 07/24/00 06/25/00 05/27/00 04/23/00 03/26/00 02/25/00 01/28/00 12/25

0.00 0.02 0.00 0.01 0.01 2.66 0.00 0.97 0.00 0.02 0.00 0.00 0.00 0.00

12/23/00 11/25/00 10/26/00 09/23/0008/25/00 07/23/00 06/24/00 05/26/00 04/22100 03/25/00 02/24100 01/27/00 12/24/9
/99

0.00 0.67 0.00 1.06 1.33 0.06 2.78 0.00 0.01 0.00 0.00 0.00 0.00 0.00

12/22/00 11/24/00 10/25/00 09/22/00 08/24/00 07/22/00 06/23/00 05/25/00 04/21/00 03/24/00 02/23/00 01 /26/
99 09/10/99

0.00 0.00 0.00 0.03 0.15 0.02 0.00 0.10 0.01 0.00 0.00 0.00 0.00 0.00

12/21 /00 11 /23/00 10/24/00 09/21/00 08/23/00 01/21 /00 06/22/00 05/24/00 04/20/00 03/23/00 02/22/00 01 /25/
2/22/99 10/21/99 09/09/99

Virginia Department of Health, Division of Shellfish Sanitation

Area 70: LYNNHAVEN BAY - Hydrographic and Bacteriological Data

2/27/00 11/29/00 10/30/00 09/27/00 08/29/00 07/27/00 06/28/00 05/30/00 04/26/00 03/29/00 02/28/00 01/31/0
)/27/99 09/15/99

EB EB	FL EB	EB EB	EB EB	EB EB	EB EB	EB EB	EB EB	FL FL	EB FL	FL FL	EB FL	FL FL	FL EB
).50.5	6.00.8	0.20.7	1.81.6	0.70.1	4.65.6	5.05.1	3.33.3	1.21.3	6.00.1	2.01.9	6.00.5	3.13.6	5.30.1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.6	9.8	16.3	20.6	24.9	24.3	25.9	16.8	12.7	13.3	10.9	2.4	6.4	15.7
23.6	24.8	22.6	22.7	23.0	21.2	21.2	23.1	19.7	21.3	22.3	19.8	23.9	21.6
12	12	12	12	12	12	12	12	12	12	12	12	12	12
1.8	9.9	14.1	19.8	25.3	25.3	27.6	17.4	13.6	15.2	13.6	3.2	5.0	15.7
23.4	24.1	22.4	20.8	21.3	14.4	16.9	18.0	17.2	18.6	20.6	8.8	23.8	20.7
25	25	25	25	25	25	25	25	25	25	25	25	25	25
1.2	9.9	14.3	17.0	25.7	25.0	27.9	17.1	13.6	16.0	13.9	3.7	4.6	15.5
23.1	23.8	22.6	20.3	20.2	11.6	8.5	12.5	14.4	18.3	20.5	4.1	23.9	19.2
NW	SE	NW	N	S	N	SW	NE	NE	NW	NW	NW	NE	NW
510	55	1520	1515	510	58	33	2530	57	1215	1215	1010	57	710

Class FC MPN's

12/27/00 11/29/00 10/30/00 09/27/00 08/29/00 07/27/00 06/28/00 05/30/00 04/26/00 03/29/00 02/28/00 01/31/00 12/28/99 1(

Virginia Department of Health, Division of Shellfish Sanitation

Area 70: LYNNHAVEN BAY - Hydrographic Data

RAINFALL	06/24/99 05/26/99 04/28/99 03/29/99 02/22/99 01/27/99 12/21/98 11/24/98 10/28/98 09/28/98 08/31198
Cumulative	
Prev. Day	0.00 0.43 0.00 0.64 0.00 0.00 0.14 0.00 0.00 0.00 3.77
Prev. 2 Days	0.02 0.46 0.00 0.64 0.00 1.26 0.14 0.00 0.00 0.00 6.77
Prev. 3 Days	0.64 0.89 0.00 0.65 0.00 1.57 0.35 0.10 0.00 0.00 7.34
Prev. 4 Days	0.64 0.89 0.39 0.66 0.00 1.57 0.52 0.11 0.00 0.00 7.45
Prev. 5 Days	0.68 0.89 0.39 0.66 0.00 1.57 0.52 0.12 0.01 0.18 7.45
Prev. 6 Days	1.22 1.18 0.39 0.95 0.00 1.57 0.52 0.13 0.01 0.18 7.45
Prev. 7 Days	2.47 1.18 0.39 1.26 0.00 1.57 2.42 0.17 0.02 0.18 7.45
OCCURRENCES	06122/99 05/24/99 04/26199 03127/99 02/20/99 01/25/99 12/19198 11/22/98 10/26/98 09126/98 08/29198
	0.00 0.43 0.00 0.64 0.00 0.00 0.14 0.00 0.00 0.00 3.77
	06/21 /99 05/23/99 04125199 03/26/9902119199 01124/99 1211819811 /21 /9810125/9809/25/98 08/28198
	0.02 0.03 0.00 0.00 0.00 1.26 0.00 0.00 0.00 0.00 3.00
	06120199 05/22/99 04/2419903/2519902118/99 01123/99 1211719811 /20/98 10124/98 09/24/98 08127/98
	0.62 0.43 0.00 0.01 0.00 0.31 0.21 0.10 0.00 0.00 0.57
	06/19/99 05/21 /99 04/23/99 03/24/99 02117/99 01 /22/99 12116/98 11 /19/98 10/23/98 09/23/98 08/26/98
	0.00 0.00 0.39 0.01 0.00 0.00 0.17 0.01 0.00 0.00 0.11
	06/18/99 05/20199 04122/99 03/23/99 02116/99 01/21/99 12/15/98 11/18/98 10/22/98 09122/98 08/25/98
	0.04 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.01 0.18 0.00
	06/17/99 05/19199 04121 /99 03/22/99 02115199 01 /20/99 12/14/9811 /171981012 1 /9809/21 /9808124198
	0.54 0.29 0.00 0.29 0.00 0.00 0.00 0.01 0.00 0.00 0.00
	06116/99 05118/99 04/20/9903121199 02114/99 01119/99 1211319811/16198 10120/98 09/20/98 08/23/98
	1.25 0.00 0.00 0.31 0.00 0.00 1.90 0.04 0.01 0.00 0.00
TIDE	
Direction	EB EB EB EB EB EB EB EB FL FL FL FL FL FL FL FL FL FL' FL FL FL
FL	FL FL FL FL FL EB FL FL
Hour	3.55.0 2.83.8 2.22.0 4.34.3 3.74.0 0.50.5 0.91.0 4.24.8 2.63.63.02.6
0.80.8	1.73.0 3.84.3 6.00.7 5.25.0
WATER	
Station	1 1 1 1 1 1 1 1 1 1 1
Temp Celsius	22.8 20.1 13.5 9.3 6.1 9.4 10.8 13.3 17.8 24.5 27.4
Salinity ppt	21.9 21.7 23.2 18.8 23.2 21.0 24.7 24.3 24.1 23.7 18.6
Station	12 12 12 12 12 12 12 12 12 12 12
Temp Celsius	25.0 22.5 16.3 10.6 5.4 10.6 11.2 13.5 17.9 25.5 28.8
Salinity ppt	19.4 19.4 21.2 16.7 23.5 17.5 22.6 24.5 23.8 22.7 12.8
Station	25 25 25 25 25 25 25 25 25 25 25
Temp Celsius	25.2 22.8 16.8 11.2 4.7 10.8 11.1 13.1 17.5 25.3 27.9
Salinity ppt	19.7 16.4 20.2 17.7 23.2 11.5 22.1 24.2 23.9 22.6 11.1

Virginia Department of Health, Division of Shellfish Sanitation

Area 70: LYNNHAVEN BAY - Hydrographic Data

Station											
Temp Celsius	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Salinity ppt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WIND	06/24/99	05/26/99	04/28/99	03/29/99	02/22/99	01 /27/99	12/21 /98	11 /24/98	10/28/98	09/28/98	08/31 /9
Ave. Direction	SE	SW	E	W	N	SW	S	NE	SW	SW	N
Min &MaxMPH	5-7	3-5	15-20	3-5	20-20	18-20	5-7	5-7	5-7	1-3	3-5

Appendix B

Use of Antibiotic Resistance Analysis (ARA) to Identify
Nonpoint Sources of Fecal Contamination
in the Lynnhaven River and Nansemond River Watersheds

Final Report presented to

The Virginia Department of Environmental Quality

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Harrisonburg, VA, 22807

December 17, 2002

Summary

The antibiotic resistance analysis (ARA) method of determining the sources of fecal contamination in natural waterways was applied to the Nansemond River and Lynnhaven River watersheds. ARA involves isolation of indicator bacteria (*E. coli*) from different known fecal samples, as well as from unknown water samples. Source identification is accomplished by using the statistical method of discriminant analysis to classify each isolate extracted from water by comparing its antibiotic resistance patterns with the resistance patterns of isolates taken from known fecal samples. The potential sources of fecal contamination in the Lynnhaven and Nansemond that were tested were birds, humans, livestock, pets and wild sources. Water samples were collected at stations along the Nansemond and Lynnhaven monthly over a 12-month period from September 2001 through August 2002. The samples were processed using ARA, and fecal coliform counts were measured to evaluate the quantity of fecal material in the water. The results indicate that birds and humans are the major sources that contribute to the fecal pollution in the Lynnhaven and Nansemond watersheds.

Introduction

Fecal contamination in natural waterways can lead to several problems, including an increased incidence of pathogens (3). Additionally, the increased levels of phosphorous and nitrogen in natural waterways due to fecal pollution can lead to algal blooms that, when degraded, result in deoxygenation of waterways (1). This situation is currently leading to a deterioration of the aquatic environment in the Chesapeake Bay. Fecal contamination in waterways has consistently been demonstrated by the presence of indicator organisms such as fecal coliforms or enterococci (3). However, differentiation of the sources of fecal contamination in waters receiving mixed agricultural and human waste is more difficult. Knowledge of the source of fecal contamination is important because humans are more susceptible to infections by pathogens found in human feces (3). Once the source is identified, steps can be taken to control the influx of fecal pollution.

Several approaches have been developed for the source identification of fecal contamination. The ratio of fecal coliforms to fecal streptococci, and the presence of certain bacteriophages as source indicators have been used (2). Another method involves DNA “fingerprinting” of fecal coliforms using pulsed field gel electrophoresis (PFGE) analysis to differentiate between the variations in restriction fragments of bacteria that are found in the feces of different hosts (2). Ribotyping uses the slight differences in ribosomal RNA in *E. coli* isolated from the feces of different hosts to identify the source of fecal pollution (2).

Antibiotic resistant bacteria can develop in animals and humans as a result of treatment with antibiotics. Our laboratory has developed antibiotic resistance analysis (ARA), which uses enterococci and *E. coli* as indicator organisms in identification of sources of fecal contamination (5). *E. coli* is a species of gram-negative, rods that ferment lactose and are able to grow at 44.5°C, and is used because it is the regulatory indicator organism for shellfish waters. In this approach, strains of *E. coli* are isolated from known fecal sources, and grown on plates containing various concentrations of 6 different antibiotics. The resulting antibiotic resistance patterns of each isolate are then analyzed using discriminant analysis, a multivariate statistical method. The results are pooled to form a "known library" of antibiotic resistance patterns from different fecal sources. Resistance patterns of isolates from natural waterways are then compared with this known library to determine the source(s) of fecal pollution in that waterway (5, 6).

In this report, ARA and fecal coliform counts were used to draw conclusions about the source(s) of fecal contamination in the watersheds of the Nansemond and Lynnhaven Rivers. The Lynnhaven River and Lynnhaven Bay are located near the city of Virginia Beach, Virginia. The Nansemond River is located near the city of Suffolk, Virginia. Both are polluted with fecal matter, and contain shellfish beds that have been closed because of high levels of fecal coliforms . Both of these rivers flow directly into the Chesapeake Bay. The possible sources of fecal contamination in these watershed have been identified as birds, humans, livestock, pets and wild sources.

Materials and Methods

Sample Collection:

Fecal and water samples were collected by Virginia Department of Health personnel as part of their regular monitoring program. Additionally, some fecal samples were collected by Howard Kator. The known fecal samples and water samples were delivered to Howard Kator's laboratory at SMS/VIMS within 6 hours of collection. The samples were filtered, and the numbers of *E. coli* present was determined using modified m-TEC agar. Filter plates were then shipped to JMU by overnight delivery.

Ten sites were sampled in the Lynnhaven watershed (Figure 1), and 7 sites were sampled in the Nansemond watershed (Figure 2) over a 12-month period from September 2001 through August 2002. The goal was to test 23 isolates from each sample, resulting in a precision of approximately 4%. Because of low counts, fewer isolates were analyzed for some samples.

To determine the effects of overnight storage on classification, duplicate sets of water samples were collected from the Lynnhaven stations in July and August. One set was filtered within 6 hours, and the other set was refrigerated overnight before filtering.

Isolation of *E. coli*:

Isolated colonies were selected (23 for unknown samples, and 10-12 for known samples) and transferred to 96-microwell plates containing 0.2 ml of Colilert broth. The microwell plates were incubated at 37°C for 24 hours. MUG-negative isolates were not analyzed.

Antibiotics:

Isolates from the 96-microwell plate were transferred to antibiotic-containing Trypticase Soy agar (TSA) plates using a sterile 48-prong replica-plater. Various concentrations of 6 antibiotics were used (25 concentrations total) (7). The isolates were also replica-plated to two TSA plates that did not contain antibiotics as a control. All TSA plates were incubated at 37°C for 24-48 hours. After incubation, the growth of each isolate on each concentration of each antibiotic was determined, and the resulting antibiotic resistance patterns were entered into an Excel spreadsheet.

Statistical Analysis:

The results from resistance testing of the known isolates were entered into the SAS statistical program where they were analyzed using the DISCRIM procedure, which produces a classification table. The average rate of correct classification (ARCC) is the average rate that known isolates are correctly classified, and was determined by averaging the percentages of correctly classified isolates for each source. For this analysis, only unique isolates in each known sample were analyzed. Thus, if two or more isolates from the same fecal sample had the same resistance pattern, only one of them was included in the library. The isolates from each water sample were then classified using this library.

To measure the representativeness of the library (i.e., how well it represents the diversity of patterns present in the sources in the watershed), all of the isolates from each known sample were successively removed from the library, and then classified based on the library containing the remaining isolates. The ARCC of these removed isolates was then calculated. This "jackknife" method estimates how well "new" isolates would be classified by the library. If there is a large difference between the ARCCs of these two methods, it suggests that the library is not representative of the sources in the watershed.

The Minimum Detectable Percentage (MDP) for this library was calculated by determining the mean of the expected frequencies of misclassification (EFM, the average percentages of other source types that were misclassified as that type) and adding the value of 4 times the standard deviation of the mean (4). This value is a conservative estimate of the minimum percentage of a source that can be detected in a stream sample. Thus, if a source is found at levels above the MDP, it can be reasonably assumed that this is not the result of misclassification of other sources, and therefore is present in the watershed.

Results

Classification of Known Isolates (Library Composition)

A total of 482 isolates were tested from the five sources, of which 244 were unique (Table 1). The isolates collected from these known fecal sources were analyzed using discriminant analysis. The average rate of correct classification (ARCC) of the library was 51%, which was well above the background level of 20% (Table 2). However, when this library was analyzed using jackknife analysis, the ARCC was just 30% (Table 3). This large reduction in classification success indicates that this small library is not representative of the watershed.

In an attempt to increase the size of the library, and thus its representativeness, these known isolates were classified using a library of known isolates from the Little Wicomico and Coan watersheds, which was produced by Dr. Charles Hagedorn at Virginia Tech. Unfortunately, the classification of the Lynnhaven and Nansemond isolates was very poor using the Little Wicomico and Coan library (ARCC = 21%). Thus, Hagedorn's library should not be used to classify the unknown isolates that were analyzed in our lab. A comparison was also made using some of the other *E. coli* libraries that were produced in our laboratory. Again, the classification of the Lynnhaven and Nansemond isolates was very poor (ARCC = 26%) using libraries from Long Glade Creek, Thumb Run, Goose Creek, and Berkeley Springs (WVA). Thus, even though the Lynnhaven and Nansemond library is small, none of the other *E. coli* libraries can be used to increase its size.

Based on the jackknife analysis, the Minimum Detectable Percentage (MDP) for the Lynnhaven and Nansemond library was calculated. The mean expected frequency of misclassification (EFM) of this library is 18% ± 5% SD (Table 3). Multiplying the SD by 4 and adding this to the mean EFM results in a MDP of 38%. The MDP, as proposed by Whitlock et al. (4), reflects the amount of misclassification that occurs for a particular library, and is a conservative estimate of the lower limit for considering a source to be a significant contributor to a watershed.

Analysis of Lynnhaven Samples

***E. coli* counts.** During the study period, 120 samples were collected. The numbers of *E. coli* in these samples, and the total amount of rainfall in the 3 days previous to the sampling are shown in Table 4 (listed by sample site) and Table 5 (listed by collection date). Forty-seven of the samples had levels of *E. coli* that were above the Virginia standard of 14 *E. coli* /100 ml. Stations L-11, L-12, L-24, and L-25 had consistently high fecal counts, with the geometric mean of the 12 monthly samples exceeding the Virginia standard. The months with the highest fecal counts were the December, January, and February samples. There appeared to be no correlation with rainfall in the fecal counts, as the December and February samples had no rain the preceding 3 days, while the January sample had substantial precipitation.

Classification using ARA. Based on the Lynnhaven and Nansemond library, the 120 samples were classified. The results are shown in Table 6 (listed by sample site) and Table 7 (listed by collection date). Bird and human sources were the most common, with 32 and 27, respectively, of the 120 samples having percentages that exceeded the Minimum Detectable Percentage of 38%. Based on the average of the 12 monthly samples, no source exceeded the MDP for any of the stations. However, some months had higher proportions of sources than others. January and August had very high levels of human isolates, and bird isolates were predominant in September, October, December, May and June. Livestock had a high level in November, but otherwise was low. Wild isolates were at their highest levels in May, June, and July. Isolates from pets were highest in the Spring and Summer months.

Comparison of 6-hour and 24-hour samples. The samples that were held overnight before processing were analyzed and compared to the 6-hour samples (Table 7K and 7L). There were some large differences, but generally there was good agreement between the sets of samples. The pairs of samples differed from each other by an average of just 16%, demonstrating that there is no appreciable difference in holding the samples overnight before processing.

Analysis of Nansemond Samples

***E. coli* counts.** During the study period, 84 samples were collected. The numbers of *E. coli* in these samples, and the total amount of rainfall in the 3 days previous to the sampling are shown in Table 8 (listed by sample site) and Table 9 (listed by collection date). Forty-eight of the samples had levels of *E. coli* that were above the Virginia standard of 14 *E. coli* /100 ml. Stations N1.5-Y, N2.4-X, N-13, and N-15 had consistently high fecal counts, with the geometric mean of the 12 monthly samples exceeding the Virginia standard. There were several months (September, November, December, January, April, and May) that had mean fecal counts above the standard, with December being the highest. Again, there was little correlation with rainfall in the fecal counts, although most of the high rainfall days had high average fecal counts.

Classification using ARA. Based on the Lynnhaven and Nansemond library, the 84 samples were classified. The results are shown in Table 10 (listed by sample site) and Table 11 (listed by collection date). As in the Lynnhaven, bird and human sources were the most common, with 20 and 19, respectively, of the 84 samples having percentages that exceeded the Minimum Detectable Percentage of 38%. Based on the average of the 12 monthly samples, no source exceeded the MDP for any of the stations. However, some months had higher proportions of sources than others. January had high levels of human isolates, and bird isolates were predominant in June. Wild isolates were at their highest levels in November. Isolates from pets were highest in the Spring and Summer months.

<u>Discussion</u>

These results show that birds and humans are the major sources of pollution in both the Lynnhaven and Nansemond watersheds. Table 12 (Lynnhaven) and Table 13 (Nansemond) show the sources of fecal contamination for each sample that were above the MDP. Both watersheds show similar sources. All the sites had samples that contained percentages of both bird and human sources that were at or above the minimum detectable level. Bird accounted for 35% of the samples that were above the MDP, and human accounted for 30%. The contributions of wild sources, livestock, and pets were lower, at 15%, 11%, and 9%, respectively. This pattern of sources is consistent with the land use of these watersheds, which contain large populations of humans, and are adjacent to estuarine areas that support large numbers of birds.

<u>Limitations of this study</u>. The major limitation of this study was the size of the library. Because there were just 244 unique isolates, it is very likely that many patterns of the potential sources are not represented in the library. Thus, a very high threshold of 38% was set to ensure that the chances of misidentification of the sources are small. As a result of this high threshold, some sources that are actually present could have been missed for some samples. However, when a lower MDP was applied (only 2 SD were added to the mean instead of 4), the proportions of sources did not change appreciably (32% bird, 27% human, 18% wild, 12% livestock, and 11% pets). This demonstrates that the use of the more conservative MDP did not miss any potential sources.

Another limitation is the number of isolates that were tested in some samples. Because of low fecal counts, some samples had very low isolate numbers, and the percentages that result from these low numbers are not precise (i.e., a given source in a sample with just 2 isolates can be only 0%, 50%, or 100%). So caution should be used in using the percentage values for these samples.

A third concern is the use of *E. coli* as the test organism. Although the initial studies looked promising, further work with *E. coli* in our lab has shown that it is not as effective as the enterococci for BST. Because of the higher ARCCs and larger libraries, we have chosen to focus on the enterococci for future BST projects.

Finally, it must be kept in mind that all BST methods, including ARA, are still being developed, and there are no "standard methods" yet for any method. There are many variables that determine the sources of fecal bacteria in water, and many of them are poorly understood.

Acknowledgments

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Figure 1. Sampling stations in the Lynnhaven watershed. Map courtesy of Howard Kator and Julie Herman from VIMS.

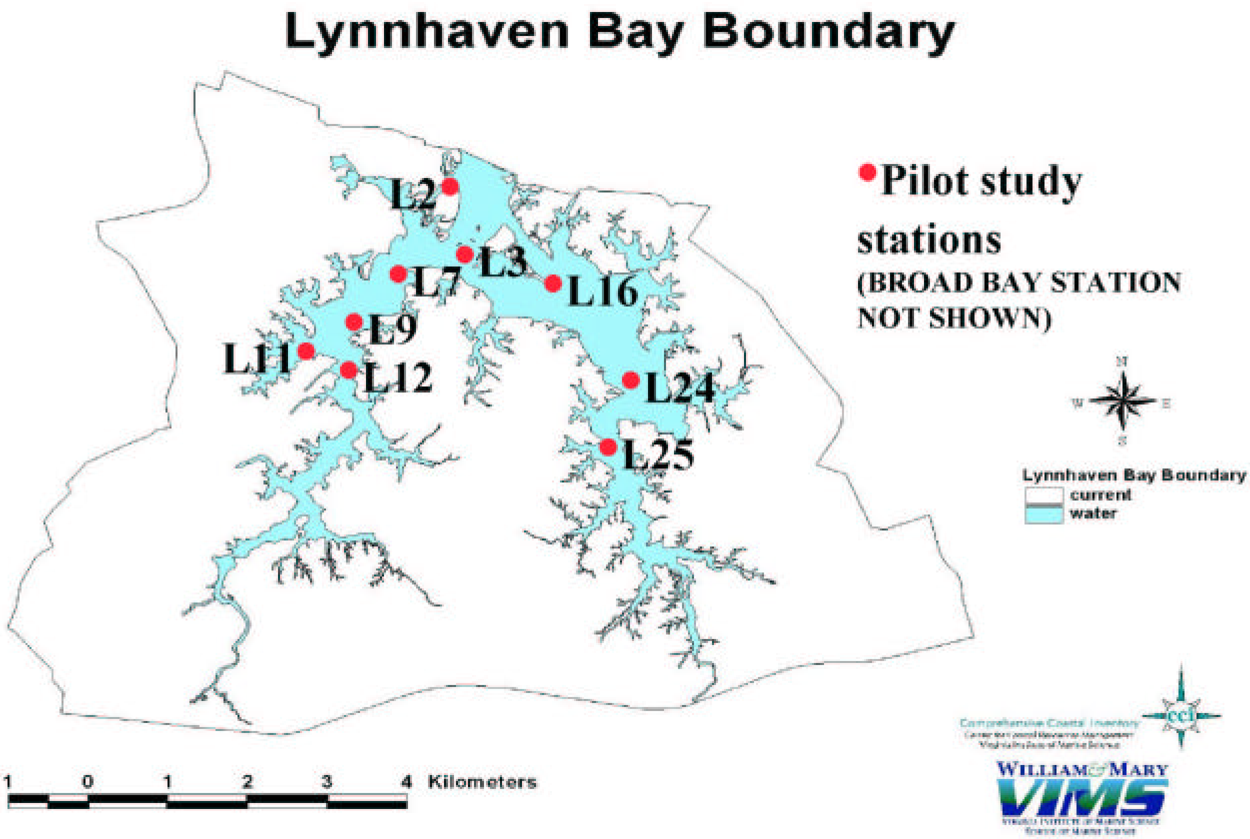

Figure 2. Sampling stations in the Nansemond watershed. Map courtesy of Howard Kator and Julie Herman from VIMS.

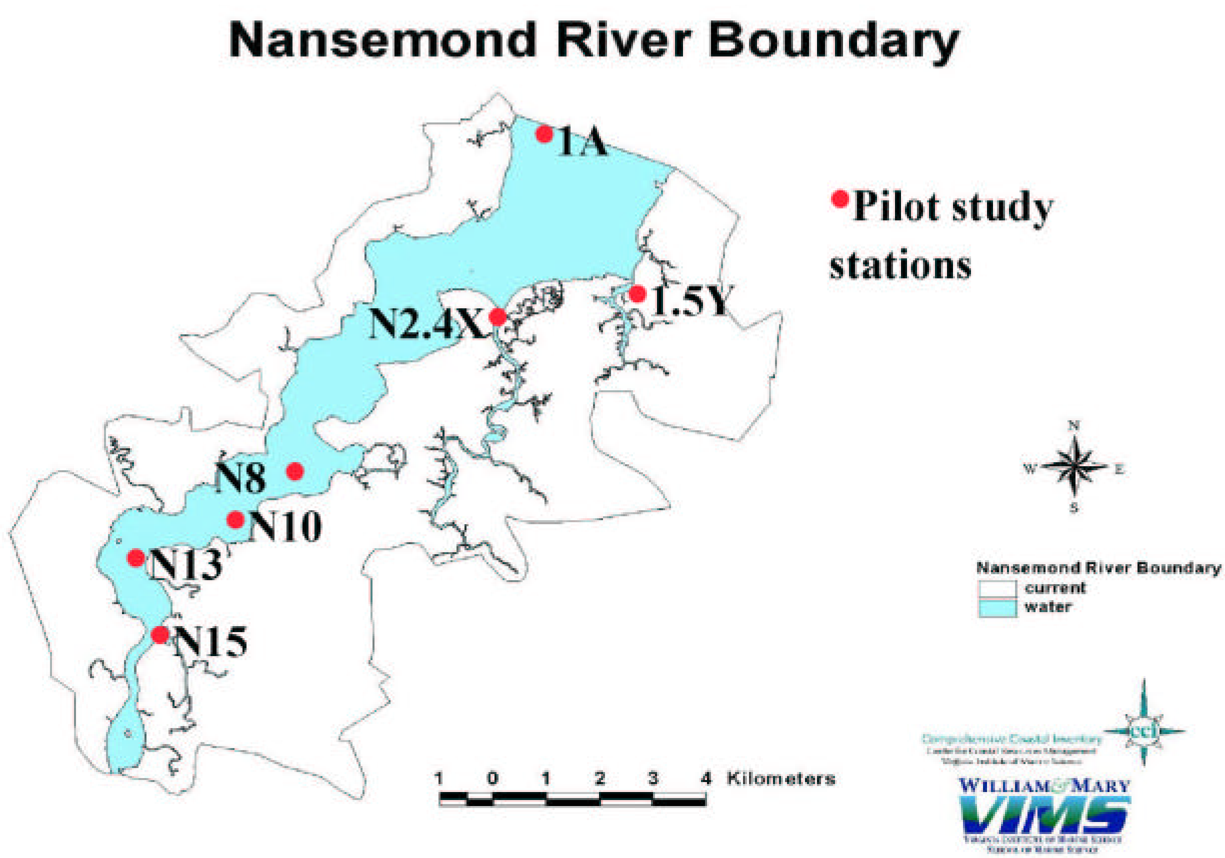

Table 1. Numbers of known fecal samples and isolates comprising the library used in this study, and how they were pooled for discriminant analysis.

Source	# of Samples	Total # of Isolates	# of Unique Isolates
Birds	4	63	36
Human	11	96	47
Livestock	9	89	59
Pets	11	139	54
Wildlife	12	95	48
Totals	47	482	244

Table 2. Classification of 244 isolates of *E. coli* from known bird, human, livestock, pet, and wild sources collected in the Nansemond and Lynnhaven watersheds. Correctly-classified isolates are shown in bold. The ARCC for this analysis is 51%.

	Number (and Percent) of Isolates Classified As:				
SOURCE	BIRD	HUMAN	LIVESTOCK	PETS	WILDLIFE
BIRD (n = 36)	**21 (58)**	2 (6)	5 (14)	6 (17)	2 (5)
HUMAN (n = 47)	8 (17)	**24 (51)**	1 (2)	5 (11)	9 (19)
LIVESTOCK (n=59)	17 (29)	5 (8)	**27 (46)**	7 (12)	3 (5)
PETS (n=54)	20 (37)	6 (11)	3 (5)	**16 (30)**	9 (17)
WILD (n=48)	2 (5)	4 (8)	4 (8)	4 (8)	**34 (71)**

Table 3. Cross-validation analysis of 244 isolates of *E. coli* from known bird, human, livestock, pet, and wild sources collected in the Nansemond and Lynnhaven watersheds. Correctly-classified isolates are shown in bold. The ARCC for this analysis is 30%, the mean expected frequency of misclassification (EFM) is 18% ± 5% SD, and the MDP is 38%.

	Number (and Percent) of Isolates Classified As:				
SOURCE	BIRD	HUMAN	LIVESTOCK	PETS	WILDLIFE
BIRD (n = 36)	**11 (31)**	2 (6)	11 (31)	10 (28)	2 (6)
HUMAN (n = 47)	11 (23)	**11 (23)**	3 (7)	10 (21)	12 (26)
LIVESTOCK (n=59)	19 (32)	7 (12)	**19 (32)**	7 (12)	7 (12)
PETS (n=54)	21 (39)	6 (11)	8 (15)	**8 (15)**	11 (20)
WILD (n=48)	3 (6)	7 (15)	9 (19)	5 (10)	**24 (50)**
EFM	25	11	18	18	16

Table 12. The sources of fecal contamination found in the Lynnhaven watershed. B = bird, H = human, L = livestock, P = pets, W = wildlife. "X" = above MDP.

	Site																						
Month	**L-1**						**L-2**						**L-3**						**L-7**				
	B	**H**	**L**	**P**	**W**		**B**	**H**	**L**	**P**	**W**		**B**	**H**	**L**	**P**	**W**		**B**	**H**	**L**	**P**	**W**
Sep-01	X						X						X							X			
Oct-01		X						X															
Nov-01		X																			X		
Dec-01					X						X		X						X				
Jan-02							X							X						X			
Feb-02																X							
Mar-02								X															
Apr-02	X						X									X						X	
May-02				X			X						X										
Jun-02	X						X										X		X				
Jul-02					X						X					X							X
Aug-02														X					X				

	Site																						
Month	**L-9**						**L-11**						**L-12**						**L-16**				
	B	**H**	**L**	**P**	**W**		**B**	**H**	**L**	**P**	**W**		**B**	**H**	**L**	**P**	**W**		**B**	**H**	**L**	**P**	**W**
Sep-01	X								X				X							X			
Oct-01							X						X						X		X		
Nov-01									X								X					X	
Dec-01	X						X						X							X			
Jan-02		X						X						X						X			
Feb-02									X														
Mar-02				X				X															
Apr-02		X			X						X												
May-02													X										X
Jun-02	X										X								X				X
Jul-02														X									X
Aug-02		X					X							X						X		X	

	Site										
Month	**L-24**						**L-25**				
	B	**H**	**L**	**P**	**W**		**B**	**H**	**L**	**P**	**W**
Sep-01	X						X				
Oct-01	X						X		X		
Nov-01			X						X		
Dec-01	X										
Jan-02		X						X			
Feb-02								X			
Mar-02		X									
Apr-02											
May-02											
Jun-02		X					X				
Jul-02					X						
Aug-02		X						X			

Table 13. The sources of fecal contamination found in the Nansemond watershed. B = bird, H = human, L = livestock, P = pets, W = wildlife. "X" = above MDP.

	Site																						
Month	**N-1A**						**N-1.5Y**						**N-2.4X**						**N-8**				
	B	**H**	**L**	**P**	**W**		**B**	**H**	**L**	**P**	**W**		**B**	**H**	**L**	**P**	**W**		**B**	**H**	**L**	**P**	**W**
Sep-01	X	X							X						X								
Oct-01																							
Nov-01			X								X												
Dec-01	X						X										X						X
Jan-02		X						X					X							X			
Feb-02		X					X							X					X				
Mar-02				X						X				X						X			
Apr-02																	X						
May-02							X																
Jun-02	X			X			X										X		X				
Jul-02							X																
Aug-02																	X			X		X	

	Site																
Month	**N-10**						**N-13**						**N-15**				
	B	**H**	**L**	**P**	**W**		**B**	**H**	**L**	**P**	**W**		**B**	**H**	**L**	**P**	**W**
Sep-01													X				
Oct-01																	X
Nov-01					X						X						
Dec-01	X												X				
Jan-02		X						X					X	X			
Feb-02								X					X				
Mar-02		X															
Apr-02	X	X					X							X			
May-02								X									
Jun-02							X						X				
Jul-02											X						
Aug-02		X		X						X				X			

Appendix C

1) Code of Virginia §62.1-194.1 Obstructing or contaminating state waters.

2) Code of Federal Regulations. Title 33, Volume 2, Parts 120 to 1999 Revised as of July 1, 2000

Code of Virginia §62.1-194.1

§62.1-194.1. Obstructing or contaminating state waters.

Except as otherwise permitted by law, it shall be unlawful for any person to dump, place or put, or cause to be dumped, placed or put into, upon the banks of or into the channels of any state waters any object or substance, noxious or otherwise, which may reasonably be expected to endanger, obstruct, impede,
contaminate or substantially impair the lawful use or enjoyment of such waters and their environs by others. Any person who violates any provision of this law shall be guilty of a misdemeanor and upon conviction be punished by a fine of not less than $100 nor more than $500 or by confinement in jail not more than twelve months or both such fine and imprisonment. Each day that any of said materials or substances so dumped, placed or put, or caused to be dumped, placed or put into, upon the banks of or into the channels of, said streams shall constitute a separate offense and be punished as such. In addition to the foregoing penalties for violation of this law, the judge of the circuit court of the county or corporation court of the city wherein any such violation occurs, whether there be a criminal conviction therefor or not
shall, upon a bill in equity, filed by the attorney for the Commonwealth of such county or by any person whose property is damaged or whose property is threatened with damage from any such violation, award an injunction enjoining any violation of this law by any person found by the court in such suit to have violated this law or causing the same to be violated, when made a party defendant to such suit. (1968, c. 659.)

Appendix C2

Code of Federal Regulations. Title 33, Volume 2, Parts 120 to 1999 Revised as of July 1, 2000 From the U.S. Government Printing Office via GPO Access [CITE: 33CFR159]

NAVIGABLE WATERS

CHAPTER I--COAST GUARD, DEPARTMENT OF TRANSPORTATION (CONTINUED)

PART 159--MARINE SANITATION DEVICES

Subpart A--General

Subpart B--Certification Procedures

Subpart C--Design, Construction, and Testing

Subpart D--Recognition of Facilities

Authority: Sec. 312(b)(1), 86 Stat. 871 (33 U.S.C. 1322(b)(1)); 49 CFR 1.45(b) and 1.46(l) and (m).

Source: CGD 73-83, 40 FR 4624, Jan. 30, 1975, unless otherwise noted.

Subpart A--General

Sec. 159.1 Purpose.

This part prescribes regulations governing the design and construction of marine sanitation devices and procedures for certifying that marine sanitation devices meet the regulations and the standards of the Environmental Protection Agency promulgated under section 312 of the Federal Water Pollution Control Act (33 U.S.C. 1322), to eliminate the discharge of untreated sewage from vessels into the waters of the United States, including the territorial seas. Subpart A of this part contains regulations governing the manufacture and operation of vessels equipped with marine sanitation devices.

Sec. 159.3 Definitions.

In this part:

Coast Guard means the Commandant or his authorized representative.

Discharge includes, but is not limited to, any spilling, leaking, pouring, pumping, emitting, emptying, or dumping.

Existing vessel includes any vessel, the construction of which was initiated before January 30, 1975.

Fecal coliform bacteria are those organisms associated with the intestine of warm-blooded animals that are commonly used to indicate the presence of fecal material and the potential presence of organisms capable of causing human disease.

Inspected vessel means any vessel that is required to be inspected under 46 CFR Ch. I.

Length means a straight line measurement of the overall length from the foremost part of the vessel to the aftermost part of the vessel, measured parallel to the centerline. Bow sprits, bumpkins, rudders, outboard motor brackets, and similar fittings or attachments are not to be included in the measurement.

Manufacturer means any person engaged in manufacturing, assembling, or importing of marine sanitation devices or of vessels subject to the standards and regulations promulgated under section 312 of the Federal Water Pollution Control Act.

Marine sanitation device and device includes any equipment for installation on board a vessel which is designed to receive, retain, treat, or discharge sewage, and any process to treat such sewage.

New vessel includes any vessel, the construction of which is initiated on or after January 30, 1975.

Person means an individual, partnership, firm, corporation, or association, but does not include an individual on board a public vessel.

Public vessel means a vessel owned or bare-boat chartered and operated by the United States, by a State or political subdivision thereof, or by a foreign nation, except when such vessel is engaged in commerce.

Recognized facility means any laboratory or facility listed by the Coast Guard as a recognized facility under this part.

Sewage means human body wastes and the wastes from toilets and other receptacles intended to receive or retain body waste.

Territorial seas means the belt of the seas measured from the line of ordinary low water along that portion of the coast which is in direct contact with the open sea and the line marking the seaward limit of inland waters, and extending seaward a distance of 3 miles.
Type I marine sanitation device means a device that, under the test conditions described in Secs. 159.123 and 159.125, produces an effluent having a fecal coliform bacteria count not greater than 1,000 per 100 milliliters and no visible floating solids.
Type II marine sanitation device means a device that, under the test conditions described in Secs. 159.126 and 159.126a, produces an effluent having a fecal coliform bacteria count not greater than 200 per 100 milliliters and suspended solids not greater than 150 milligrams per liter.
Type III marine sanitation device means a device that is designed to prevent the overboard discharge of treated or untreated sewage or any waste derived from sewage.
Uninspected vessel means any vessel that is not required to be inspected under 46 CFR Chapter I.
United States includes the States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, the Canal Zone, and the Trust Territory of the Pacific Islands.
Vessel includes every description of watercraft or other artificial contrivance used, or capable of being used, as a means of transportation on the waters of the United States.

[CGD 96-026, 61 FR 33668, June 28, 1996, as amended by CGD 95-028, 62 FR 51194, Sept. 30, 1997]

Sec. 159.4 Incorporation by reference.

(a) Certain material is incorporated by reference into this part with the approval of the Director of the Federal Register under 5 U.S.C. 552(a) and 1 CFR part 51. To enforce any edition other than that specified in paragraph (b) of this section, the Coast Guard must publish notice of change in the Federal Register; and the material must be available to the public. All approved material is available for inspection at the Office of the Federal Register, 800 North Capitol Street, NW., suite 700, Washington, DC, and at the U.S. Coast Guard Office of Design and Engineering Standards (G-MSE), 2100 Second Street SW., Washington, DC 20593-0001, and is available from the sources indicated in paragraph (b) of this section.
(b) The material approved for incorporation by reference in this part, and the sections affected, are as follows:

American Society for Testing and Materials (ASTM)

100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM E 11-95, Standard Specification for Wire Cloth and Sieves for
Testing Purposes--159.125

[USCG-1999-5151, 64 FR 67176, Dec. 1, 1999]

Sec. 159.5 Requirements for vessel manufacturers.

No manufacturer may manufacture for sale, sell, offer for sale, or distribute for sale or resale any vessel equipped with installed toilet facilities unless it is equipped with:

(a) An operable Type II or III device that has a label on it under Sec. 159.16 or that is certified under Sec. 159.12 or Sec. 159.12a; or

(b) An operable Type I device that has a label on it under Sec. 159.16 or that is certified under Sec. 159.12, if the vessel is 19.7 meters (65 feet) or less in length.

[CGD 95-028, 62 FR 51194, Sept. 30, 1997]

Sec. 159.7 Requirements for vessel operators.

(a) No person may operate any vessel equipped with installed toilet facilities unless it is equipped with:

(1) An operable Type II or III device that has a label on it under Sec. 159.16 or that is certified under Sec. 159.12 or Sec. 159.12a; or

(2) An operable Type I device that has a label on it under Sec. 159.16 or that is certified under Sec. 159.12, if the vessel is 19.7 meters (65 feet) or less in length.

(b) When operating a vessel on a body of water where the discharge of treated or untreated sewage is prohibited by the Environmental Protection Agency under 40 CFR 140.3 or 140.4, the operator must secure each Type I or Type II device in a manner which prevents discharge of treated or untreated sewage. Acceptable methods of securing the device include--

(1) Closing the seacock and removing the handle;

(2) Padlocking the seacock in the closed position;

(3) Using a non-releasable wire-tie to hold the seacock in the closed position; or

(4) Locking the door to the space enclosing the toilets with a padlock or door handle key lock.

(c) When operating a vessel on a body of water where the discharge of untreated sewage is prohibited by the Environmental Protection Agency under 40 CFR 140.3, the operator must secure each Type III device in a manner which prevents discharge of sewage. Acceptable methods of securing the device include--

(1) Closing each valve leading to an overboard discharge and removing the handle;

(2) Padlocking each valve leading to an overboard discharge in the closed position; or

(3) Using a non-releasable wire-tie to hold each valve leading to an overboard discharge in the closed position.

[CGH 95-028, 62 FR 51194, Sept. 30, 1997]

Subpart B--Certification Procedures

Sec. 159.11 Purpose.

This subpart prescribes procedures for certification of marine sanitation devices and authorization for labels on certified devices.

Sec. 159.12 Regulations for certification of existing devices.

(a) The purpose of this section is to provide regulations for certification of existing devices until manufacturers can design and manufacture devices that comply with this part and recognized facilities are prepared to perform the testing required by this part.
(b) Any Type III device that was installed on an existing vessel before January 30, 1975, is considered certified.
(c) Any person may apply to the Commandant (G-MSE), U.S. Coast Guard, Washington, D.C. 20593-0001 for certification of a marine sanitation device manufactured before January 30, 1976. The Coast Guard will issue a letter certifying the device if the applicant shows that the device meets Sec. 159.53 by:
(1) Evidence that the device meets State standards at least equal to the standards in Sec. 159.53, or
(2) Test conducted under this part by a recognized laboratory, or
(3) Evidence that the device is substantially equivalent to a device certified under this section, or
(4) A Coast Guard field test if considered necessary by the Coast Guard.
(d) The Coast Guard will maintain and make available a list that identifies each device certified under this section.
(e) Devices certified under this section in compliance with Sec. 159.53 need not meet the other regulations in this part and may not be labeled under Sec. 159.16.

[CGD 73-83, 40 FR 4624, Jan. 30, 1975, as amended by CGD 75-213, 41 FR 15325, Apr. 12, 1976; CGD 82-063a, 48 FR 4776, Feb. 3, 1983; CGD 88-052, 53 FR 25122, July 1, 1988; CGD 96-026, 61 FR 33668, June 28, 1996]

Sec. 159.12a Certification of certain Type III devices.

(a) The purpose of this section is to provide regulations for certification of certain Type III devices.
(b) Any Type III device is considered certified under this section if:
(1) It is used solely for the storage of sewage and flushwater at ambient air pressure and temperature; and
(2) It is in compliance with Sec. 159.53(c).
(c) Any device certified under this section need not comply with the other regulations in this part except as required in paragraphs (b)(2)and (d) of this section and may not be labeled under Sec. 159.16.
d) Each device certified under this section which is installed aboard an inspected vessel must comply with Sec. 159.97.

[CGD 76-145, 42 FR 11, Jan. 3, 1977]

Sec. 159.14 Application for certification.

(a) Any manufacturer may apply to any recognized facility for certification of a marine sanitation device. The application for certification must indicate whether the device will be used aboard all vessels or only aboard uninspected vessels and to which standard in Sec. 159.53 the manufacturer requests the device to be tested.

(b) An application may be in any format but must be in writing and must be signed by an authorized representative of the manufacturer and include or be accompanied by:

(1) A complete description of the manufacturer's production quality control and inspection methods, record keeping systems pertaining to the manufacture of marine sanitation devices, and testing procedures;

(2) The design for the device, including drawings, specifications and other information that describes the materials, construction and operation of the device;

(3) The installation, operation, and maintenance instructions for the device; and

(4) The name and address of the applicant and the manufacturing facility.

(c) The manufacturer must furnish the recognized facility one device of each model for which certification is requested and samples of each material from which the device is constructed, that must be tested destructively under Sec. 159.117. The device furnished is for the testing required by this part except that, for devices that are not suited for unit testing, the manufacturer may submit the design so that the recognized facility may determine the components of the device and materials to be submitted for testing and the tests to be performed at a place other than the facility. The Coast Guard must review and accept all such determinations before testing is begun.

(d) At the time of submittal of an application to a recognized facility the manufacturer must notify the Coast Guard of the type and model of the device, the name of the recognized facility to which application is being made, and the name and address of the manufacturer, and submit a signed statement of the times when the manufacturer will permit designated officers and employees of the Coast Guard to have access to the manufacturer's facilities and all records required by this part.

[CGD 73-83, 40 FR 4624, Jan. 30, 1975, as amended by CGD 75-213, 41 FR 15325, Apr. 12, 1976]

Sec. 159.15 Certification.

(a) The recognized facility must evaluate the information that is submitted by the manufacturer in accordance with Sec. 159.14(b) (1), (2), and (3), evaluate the device for compliance with Secs. 159.53 through 159.95, test the device in accordance with Sec. 159.101 and submit to the Commandant (G-MSE), U.S. Coast Guard, Washington, D.C. 20593-0001 the following:

(1) The information that is required under Sec. 159.14(b);

(2) A report on compliance evaluation;

(3) A description of each test;

(4) Test results; and

(5) A statement, that is signed by the person in charge of testing, that the test results are accurate and complete.

(b) The Coast Guard certifies a test device, on the design of the device, if it determines, after consideration of the information that is required under paragraph (a) of this section, that the device meets the requirements in Subpart C of this part.

(c) The Coast Guard notifies the manufacturer and recognized facility of its determination under paragraph (b) of this section. If the device is certified, the Coast Guard includes a certification number for the device. If certification is denied, the Coast Guard notifies the manufacturer and recognized facility of the requirements of this part that are not met. The manufacturer may appeal a denial to the Commandant (G-MSE), U.S. Coast Guard, Washington, D.C. 20593-0001.

(d) If upon re-examination of the test device, the Coast Guard determines that the device does not in fact comply with the requirements of Subpart C of this part, it may terminate the certification.

[CGD 73-83, 40 FR 4624, Jan. 30, 1975, as amended by CGD 75-213, 41 FR 15326, Apr. 12, 1976; CGD 82-063a, 48 FR 4776, Feb. 3, 1983; CGD 88-052, 53 FR 25122, July 1, 1988; CGD 96-026, 61 FR 33668, June 28, 1996]

Sec. 159.16 Authorization to label devices.

(a) When a test device is certified under Sec. 159.15(b), the Coast Guard will issue a letter that authorizes the manufacturer to label each device that he manufactures with the manufacturer's certification that the device is in all material respects substantially the same as a test device certified by the U.S. Coast Guard pursuant to section 312 of the Federal Water Pollution Control Act Amendments of 1972.

(b) Certification placed on a device by its manufacturer under this section is the certification required by section 312(h)(4) of the Federal Water Pollution Control Act Amendments of 1972, which makes it unlawful for a vessel that is subject to the standards and regulations promulgated under the Act to operate on the navigable waters of the United States, if such vessel is not equipped with an operable marine sanitation device certified pursuant to section 312 of the Act.

(c) Letters of authorization issued under this section are valid for 5 years, unless sooner suspended, withdrawn, or terminated and may be reissued upon written request of the manufacturer to whom the letter was issued.

(d) The Coast Guard, in accordance with the procedure in 46 CFR 2.75, may suspend, withdraw, or terminate any letter of authorization issued under this section if the Coast Guard finds that the manufacturer is engaged in the manufacture of devices labeled under this part that are not in all material respects substantially the same as a test device certified pursuant to this part.

Sec. 159.17 Changes to certified devices.

(a) The manufacturer of a device that is certified under this part shall notify the Commandant (G-MSE), U.S. Coast Guard, Washington, D.C. 20593-0001 in writing of any change in the design of the device.

(b) A manufacturer shall include with a notice under paragraph (a) of this section a description of the change, its advantages, and the recommendation of the recognized facility as to whether the device remains in all material respects substantially the same as the original test device.

(c) After notice under paragraph (a) of this section, the Coast Guard notifies the manufacturer and the recognized facility in writing of any tests that must be made for certification of the device or for any change in the letter of authorization. The manufacturer may appeal this determination to the Commandant (G-MSE), U.S. Coast Guard, Washington, D.C. 20593-0001.

[CGD 73-83, 40 FR 4624, Jan. 30, 1975, as amended by CGD 82-063a, 48 FR 4776, Feb. 3, 1983; CGD 88-052, 53 FR 25122, July 1, 1988; CGD 96-026, 61 FR 33668, June 28, 1996]

Sec. 159.19 Testing equivalency.

(a) If a test required by this part may not be practicable or necessary, a manufacturer may apply to the Commandant (G-MSE), U.S. Coast Guard, Washington, DC 20593-0001 for deletion or approval of an alternative test as equivalent to the test requirements in this part. The application must include the manufacturer's justification for deletion or the alternative test and any alternative test data.

(b) The Coast Guard notifies the manufacturer of its determination under paragraph (a) of this section and that determination is final.

[CGD 73-83, 40 FR 4624, Jan. 30, 1975, as amended by CGD 82-063a, 48 FR 4776, Feb. 3, 1983; CGD 88-052, 53 FR 25122, July 1, 1988; CGD 96-026, 61 FR 33668, June 28, 1996]

Subpart C--Design, Construction, and Testing

Sec. 159.51 Purpose and scope.

(a) This subpart prescribes regulations governing the design and construction of marine sanitation devices.

(b) Unless otherwise authorized by the Coast Guard each device for which certification under this part is requested must meet the requirements of this subpart.

Sec. 159.53 General requirements.

A device must:

(a) Under the test conditions described in Secs. 159.123 and 159.125, produce an effluent having a fecal coliform bacteria count not greater than 1,000 per 100 milliliters and no visible floating solids (Type I),

(b) Under the test conditions described in Secs. 159.126 and 159.126a, produce an effluent having a fecal coliform bacteria count not greater than 200 per 100 milliliters and suspended solids not greater than 150 milligrams per liter (Type II), or

(c) Be designed to prevent the overboard discharge of treated or untreated sewage or any waste derived from sewage (Type III).

[CGD 73-83, 40 FR 4624, Jan. 30, 1975, as amended by CGD 75-213, 41 FR 15325, Apr. 12, 1976]

Sec. 159.55 Identification.

(a) Each production device must be legibly marked in accordance with paragraph (b) of this section with the following information:
(1) The name of the manufacturer.
(2) The name and model number of the device.
(3) The month and year of completion of manufacture.
(4) Serial number.
(5) Whether the device is certified for use on an inspected or an uninspected vessel.
(6) Whether the device is Type I, II, or III.
(b) The information required by paragraph (a) of this section must appear on a nameplate attached to the device or in lettering on the device. The nameplate or lettering stamped on the device must be capable of withstanding without loss of legibility the combined effects of normal wear and tear and exposure to water, salt spray, direct sunlight, heat, cold, and any substance listed in Sec. 159.117(b) and (c). The nameplate and lettering must be designed to resist efforts to remove them from the device or efforts to alter the information stamped on the nameplate or the device without leaving some obvious evidence of the attempted removal or alteration.

[CGD 73-83, 40 FR 4624, Jan. 30, 1975, as amended by CGD 75-213, 41 FR 15325, Apr. 12, 1976]

Sec. 159.57 Installation, operation, and maintenance instructions.

(a) The instructions supplied by the manufacturer must contain directions for each of the following:
(1) Installation of the device in a manner that will permit ready access to all parts of the device requiring routine service and that will provide any flue clearance necessary for fire safety.
(2) Safe operation and servicing of the device so that any discharge meets the applicable requirements of Sec. 159.53.
(3) Cleaning, winter layup, and ash or sludge removal.
(4) Installation of a vent or flue pipe.
(5) The type and quantity of chemicals that are required to operate the device, including instructions on the proper handling, storage and use of these chemicals.
(6) Recommended methods of making required plumbing and electrical connections including fuel connections and supply circuit overcurrent protection.
(b) The instructions supplied by the manufacturer must include the following information:
(1) The name of the manufacturer.
(2) The name and model number of the device.
(3) Whether the device is certified for use on an inspected, or uninspected vessel.

(4) A complete parts list.
(5) A schematic diagram showing the relative location of each part.
(6) A wiring diagram.
(7) A description of the service that may be performed by the user without coming into contact with sewage or chemicals.
(8) Average and peak capacity of the device for the flow rate, volume, or number of persons that the device is capable of serving and the period of time the device is rated to operate at peak capacity.
(9) The power requirements, including voltage and current.
(10) The type and quantity of fuel required.
(11) The duration of the operating cycle for unitized incinerating devices.
(12) The maximum angles of pitch and roll at which the device operates in accordance with the applicable requirements of Sec. 159.53.
(13) Whether the device is designed to operate in salt, fresh, or brackish water.
(14) The maximum hydrostatic pressure at which a pressurized sewage retention tank meets the requirements of Sec. 159.111.
(15) The maximum operating level of liquid retention components.
(16) Whether the device is Type I, II, or III.
(17) A statement as follows:
Note: The EPA standards state that in freshwater lakes, freshwater reservoirs or other freshwater impoundments whose inlets or outlets are such as to prevent the ingress or egress by vessel traffic subject to this regulation, or in rivers not capable of navigation by interstate vessel traffic subject to this regulation, marine sanitation devices certified by the U.S. Coast Guard installed on all vessels shall be designed and operated to prevent the overboard discharge of sewage, treated or untreated, or of any waste derived from sewage. The EPA standards further state that this shall not be construed to prohibit the carriage of Coast Guard-certified flow-through treatment devices which have been secured so as to prevent such discharges. They also state that waters where a Coast Guard-certified marine sanitation device permitting discharge is allowed include coastal waters and estuaries, the Great Lakes and interconnected waterways, freshwater lakes and impoundments accessible through locks, and other flowing waters that are navigable interstate by vessels subject to this regulation (40 CFR 140.3).

[CGD 73-83, 40 FR 4624, Jan. 30, 1975, as amended by CGD 75-213, 41 FR 15325, Apr. 12, 1976]

Sec. 159.59 Placard.

Each device must have a placard suitable for posting on which is printed the operating instructions, safety precautions, and warnings pertinent to the device. The size of the letters printed on the placard must be one-eighth of an inch or larger.

Sec. 159.61 Vents.

Vents must be designed and constructed to minimize clogging by either the contents of the tank or climatic conditions such as snow or ice.

Sec. 159.63 Access to parts.

Each part of the device that is required by the manufacturer's instructions to be serviced routinely must be readily accessible in the installed position of the device recommended by the manufacturer.

Sec. 159.65 Chemical level indicator.

The device must be equipped with one of the following:

(a) A means of indicating the amount in the device of any chemical that is necessary for its effective operation.

(b) A means of indicating when chemicals must be added for the proper continued operation of the device.

Sec. 159.67 Electrical component ratings.

Electrical components must have current and voltage ratings equal to or greater than the maximum load they may carry.

Sec. 159.69 Motor ratings.

Motors must be rated to operate at 50 deg.C ambient temperature.

Sec. 159.71 Electrical controls and conductors.

Electrical controls and conductors must be installed in accordance with good marine practice. Wire must be copper and must be stranded. Electrical controls and conductors must be protected from exposure to chemicals and sewage.

Sec. 159.73 Conductors.

Current carrying conductors must be electrically insulated from non-current carrying metal parts.

Sec. 159.75 Overcurrent protection.

Overcurrent protection must be provided within the unit to protect subcomponents of the device if the manufacturer's recommended supply circuit overcurrent protection is not adequate for these subcomponents.

Sec. 159.79 Terminals.

Terminals must be solderless lugs with ring type or captive spade ends, must have provisions for being locked against movement from vibration, and must be marked for identification on the wiring diagram required in Sec. 159.57. Terminal blocks must be nonabsorbent and securely mounted. Terminal blocks must be provided with barrier insulation that prevents contact between adjacent terminals or metal surfaces.

Sec. 159.81 Baffles.

Baffles in sewage retention tanks, if any, must have openings to allow liquid and vapor to flow freely across the top and bottom of the tank.

Sec. 159.83 Level indicator.

Each sewage retention device must have a means of indicating when the device is more than \3/4\ full by volume.

Sec. 159.85 Sewage removal.

The device must be designed for efficient removal of nearly all of the liquid and solids in the sewage retention tank.

Sec. 159.87 Removal fittings.

If sewage removal fittings or adapters are provided with the device, they must be of either 1\1/2\" or 4" nominal pipe size.

Sec. 159.89 Power interruption: Type I and II devices.

A discharge device must be designed so that a momentary loss of power during operation of the device does not allow a discharge that does not meet the requirements in Sec. 159.53.

[CGD 73-83, 40 FR 4624, Jan. 30, 1975, as amended by CGD 75-213, 41 FR 15326, Apr. 12, 1976]

Sec. 159.93 Independent supporting.

The device must have provisions for supporting that are independent from connecting pipes.

Sec. 159.95 Safety.

(a) Each device must--

(1) Be free of design defects such as rough or sharp edges that may cause bodily injuries or that would allow toxic substances to escape to the interior of the vessel;

(2) Be vented or provided with a means to prevent an explosion or over pressurization as a result of an accumulation of gases; and

(3) Meet all other safety requirements of the regulations applicable to the type of vessel for which it is certified.

(b) A chemical that is specified or provided by the manufacturer for use in the operation of a device and is defined as a hazardous material in 46 CFR Part 146 must be certified by the procedures in 46 CFR Part 147.

(c) Current carrying components must be protected from accidental contact by personnel operating or routinely servicing the device. All current carrying components must as a minimum be of drip-proof construction or be enclosed within a drip-proof compartment.

Sec. 159.97 Safety: inspected vessels.

The Commandant approves the design and construction of devices to be certified for installation and operation on board inspected vessels on the basis of tests and reports of inspection under the applicable marine engineering requirements in Subchapter F of Title 46, Code of Federal Regulations, and under the applicable electrical engineering requirements in Subchapter J of Title 46 Code of Federal Regulations.

[CGD 73-83, 40 FR 4624, Jan. 30, 1975, as amended by CGD 75-213, 41 FR 15326, Apr. 12, 1976]

Sec. 159.101 Testing: general.

Unless otherwise authorized by the Coast Guard, a recognized facility must perform each test described in Secs. 159.103 through 159.131. The same device must be used for each test and tested in the order in which the tests are described. There must be no cracking, softening, deterioration, displacement, breakage, leakage or damage of components or materials that affects the operation or safety of the device after each test described in Secs. 159.103 through 159.117 and Sec. 159.121, and the device must remain operable after the test described in Sec. 159.119. The device must be set up in a manner simulating installation on a vessel in accordance with the manufacturer's instructions with respect to mounting, water supply, and discharge fittings.

[CGD 73-83, 40 FR 4624, Jan. 30, 1975, as amended by CGD 75-213, 41 FR 15326, Apr. 12, 1976]

Sec. 159.103 Vibration test.

The device, with liquid retention components, if any, filled with water to one-half of their volume, must be subjected to a sinusoidal vibration for a period of 12 hours, 4 hours in each of the x, y, and z planes, at the resonant frequency of the device (or at 55 cycles per second if there is no resonant frequency between 10 to 60 hertz) and with a peak amplitude of 0.019 to 0.021 inches.

Sec. 159.105 Shock test.

The device, with liquid retention components, if any, filled with water to half of their volume, must be subjected to 1,000 vertical shocks that are ten times the force of gravity (10g) and have a duration of 20-25 milliseconds measured at the base of the half-sine shock envelope.

Sec. 159.107 Rolling test.

(a) The device, with liquid retention components, if any, filled with water to half of their volume, must be subjected to 100 cycles with the axis of rotation 4 feet from the centerline of the device, no more than 6 inches below the plane of the bottom of the device, and parallel to any tank baffles. The device must then be rotated 90 degrees on its vertical axis and subjected to another 100 cycles. This testing must be repeated with the liquid retention components filled to the maximum operating level as specified by the manufacturer in Sec. 159.57.

(b) Eighty percent of the rolling action must be approximately 15 degrees on either side of the vertical and at a cyclic rate of 3 to 4 seconds. Twenty percent motions must be approximately 30 degrees, or the maximum angle specified by the manufacturer under Sec. 159.57, whichever is greater, on either side of the vertical at a cyclic rate of 6 to 8 seconds.

Sec. 159.109 Pressure test.

Any sewage retention tank that is designed to operate under pressure must be pressurized hydrostatically at a pressure head of 7 feet or to 150 percent of the maximum pressure specified by the manufacturer for operation of the tank, whichever is greater. The tank must hold the water at this pressure for 1 hour with no evidence of leaking.

Sec. 159.111 Pressure and vacuum pulse test.

Liquid retention components of the device with manufacturer specified venting installed must be subjected to 50 fillings of water at a pressure head of 7 feet or the maximum pressure specified by the manufacturer for operation of the device, whichever is greater, and then emptied with a 45 gallon per minute or larger positive displacement pump that remains in operation 30 seconds after emptying the tank at the end of each cycle.

Sec. 159.115 Temperature range test.

(a) The device must be held at a temperature of 60 deg.C or higher for a period of 16 hours.

(b) The device must be held at a temperature of -40 deg.C or less for a period of 16 hours following winterization in accordance with manufacturers' instructions.

Sec. 159.117 Chemical resistance test.

(a) In each case where the recognized facility doubts the ability of a material to withstand exposure to the substances listed in paragraphs (b) and (c) of this section a sample of the material must be tested.

(b) A sample referred to in paragraph (a) of this section must be partially submerged in each of the following substances for 100 hours at an ambient temperature of 22 deg.C.

(1) Sewage.

(2) Any disinfectant that is required in the operation of the device.

(3) Any chemical compound in solid, liquid or gaseous form, used, emitted or produced in the operation of the device.

(4) Fresh or salt (3.5 percent Sodium Chloride) flush water.
(5) Toilet bowl cleaners.
(6) Engine Oil (SAE/30).
(7) Ethylene Glycol.
(8) Detergents (household and bilge cleaning type).

(c) A sample of the material must be doused 20 times, with a 1 hour drying period between dousings, in each of the following substances:
(1) Gasoline.
(2) Diesel fuel.
(3) Mineral spirits.
(4) Turpentine.
(5) Methyl alcohol.

Sec. 159.119 Operability test; temperature range.

The device must operate in an ambient temperature of 5 deg.C with inlet operating fluid temperature varying from 2 deg.C to 32 deg.C and in an ambient temperature of 50 deg.C with inlet operating fluid temperature varying from 2 deg.C to 32 deg.C.

Sec. 159.121 Sewage processing test.

(a) The device must process human sewage in the manner for which it is designed when tested in accordance with this section. There must be no sewage or sewage-treating chemicals remaining on surfaces or in crevices that could come in contact with a person using the device or servicing the device in accordance with the instructions supplied under Sec. 159.57(b)(7).

(b) During the test the device must be operated and maintained in accordance with the manufacturer's instructions. Any initial start-up time specified by the manufacturer must be allowed before test periods begin. For 1 hour of each 8-hour test period, the device must be tilted to the maximum angles specified by the manufacturer under Secs. 159.55 and 159.57.

(c) Except for devices described in paragraph (d) of this section, the devices must process and discharge or store human sewage over at least an 8-consecutive hour period on at least 10 days within a 20-day period. The device must receive human sewage consisting of fecal matter, urine, and toilet paper in a ratio of four urinations to one defecation with at least one defecation per person per day. Devices must be tested at their average rate of capacity as specified in Sec. 159.57. In addition, during three periods of each day the system must process sewage at the peak capacity for the period of time it is rated at peak capacity.

(d) A device that processes and discharges continuously between individual use periods or a large device, as determined by the Coast Guard, must process and discharge sewage over at least 10-consecutive days at the average daily capacity specified by the manufacturer. During three periods of each day the system must process sewage at the peak capacity for the period of time it is rated at peak capacity. The sewage for this test must be fresh, domestic sewage to which primary sludge has been added, as necessary, to create a test sewage with a minimum of 500 miligrams of suspended solids per liter.

Sec. 159.123 Coliform test: Type I devices.

(a) The arithmetic mean of the fecal coliform bacteria in 38 of 40 samples of effluent discharged from a Type I device during the test described in Sec. 159.121 must be less than 1000 per 100 milliliters when tested in accordance with 40 CFR Part 136.

(b) The 40 samples must be taken from the device as follows: During each of the 10-test days, one sample must be taken at the beginning, middle, and end of an 8-consecutive hour period with one additional sample taken immediately following the peak capacity processing period.

[CGD 73-83, 40 FR 4624, Jan. 30, 1975, as amended by CGD 75-213, 41 FR 15326, Apr. 12, 1976]

Sec. 159.125 Visible floating solids: Type I devices.

During the sewage processing test (Sec. 159.121) 40 effluent samples of approximately 1 liter each shall be taken from a Type I device at the same time as samples taken in Sec. 159.123 and passed expeditiously through a U.S. Sieve No. 12 as specified in ASTM E 11 (incorporated by reference, see Sec. 159.4). The weight of the material retained on the screen after it has been dried to a constant weight in an oven at 103 deg.C. must be divided by the volume of the sample and expressed as milligrams per liter. This value must be 10 percent or less of the total suspended solids as determined in accordance with 40 CFR Part 136 or at least 38 of the 40 samples.

Note: 33 U.S.C. 1321(b)(3) prohibits discharge of harmful quantities of oil into or upon the navigable waters of the United States or adjoining shorelines or into or upon the waters of the contiguous zone. Under 40 CFR 110.3 and 110.4 such discharges of oil include discharges which:

(a) Violate applicable water quality standards, or

(b) Cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines. If a sample contains a quantity of oil determined to be harmful, the Coast Guard will not certify the device.

[CGD 73-83, 40 FR 4624, Jan. 30, 1975, as amended by CGD 75-213, 41 FR 15326, Apr. 12, 1976; USCG-1999-5151, 64 FR 67176, Dec. 1, 1999]

Sec. 159.126 Coliform test: Type II devices.

(a) The arithmetic mean of the fecal coliform bacteria in 38 of 40 samples of effluent from a Type II device during the test described in Sec. 159.121 must be 200 per 100 milliliters or less when tested in accordance with 40 CFR Part 136.

(b) The 40 samples must be taken from the device as follows: During each of the 10 test days, one sample must be taken at the beginning, middle and end of an 8-consecutive hour period with one additional sample taken immediately following the peak capacity processing period.

[CGD 75-213, 41 FR 15326, Apr. 12, 1976]

Sec. 159.126a Suspended solids test: Type II devices.

During the sewage processing test (Sec. 159.121) 40 effluent samples must be taken at the same time as samples are taken for Sec. 159.126 and they must be analyzed for total suspended solids in accordance with 40 CFR Part 136. The arithmetic mean of the total suspended solids in 38 of 40 of these samples must be less than or equal to 150 milligrams per liter.

[CGD 75-213, 41 FR 15326, Apr. 12, 1976]

Sec. 159.127 Safety coliform count: Recirculating devices.

Thirty-eight of forty samples of flush fluid from a re-circulating device must have less than 240 fecal coliform bacteria per 100 milliliters. These samples must be collected in accordance with Sec. 159.123(b) and tested in accordance with 40 CFR Part 136.

[CGD 73-83, 40 FR 4624, Jan. 30, 1975, as amended by CGD 75-213, 41 FR 15326, Apr. 12, 1976]

Sec. 159.129 Safety: Ignition prevention test.

(a) Components of a device that are a potential ignition source in an explosive atmosphere must pass the test in paragraph (b) or (c) of this section or meet the requirements of paragraph (d) or have a specific warning in the instruction manual required by Sec. 159.57 that the device should not be installed in an explosive atmosphere.

(b) Components protected by vapor exclusion must be placed in a chamber filled with a rich mixture of gasoline or propane in air with the pressure being varied from 0 to 2 psig once an hour for 8 hours. Vapor readings must be taken in the void being protected and must indicate a leakage less than 20 percent of the lower explosive limit of the mixture in the chamber.

(c) Components providing ignition protection by means other than vapor exclusion must be fitted with an ignition source, such as a spark plug, and a means of injecting an explosive mixture of gasoline or propane and air into the void that protects the component. Connections must be made so as to minimize any additional volume added to the protected void by the apparatus delivering the explosive mixture. The component must be placed in a chamber filled with an explosive mixture and there must be no ignition of the explosive mixture surrounding the component when the following tests are conducted:

(1) Using any overload protection that is part of the device, the potential ignition source must be operated for one half hour at 110 percent of its rated voltage, one half hour at 50 percent of its rated voltage and one half hour at 100 percent of its rated voltage with the motor or armature locked, if the potential ignition source is a motor or part of a motor's electrical circuit.

(2) With the explosive mixture in the protected void, the test installed ignition source must be activated 50 times.

(3) The tests paragraphs (c) (1) and (2) of this section must be repeated with any plugs removed.

(d) Components that are certified as being intrinsically safe in accordance with the Instrument Society of America (RP 12.2) or explosion proof in accordance with the Underwriters Laboratories STD 698 in Class I, Group D hazardous locations (46 CFR 111.80-5(a)) need not be subjected to this testing.

Sec. 159.131 Safety: Incinerating device.

An incinerating device must not incinerate unless the combustion chamber is closed, must purge the combustion chamber of combustible fuel vapors before and after incineration must secure automatically if the burner does not ignite, must not allow an accumulation of fuel, and must neither produce a temperature on surfaces adjacent to the incineration chamber higher than 67 deg.C nor produce a temperature on surfaces in normal body contact higher than 41 deg.C when operating in an ambient temperature of 25 deg.C. Unitized incineration devices must completely burn to a dry, inert ash, a simultaneous defecation and urination and must not discharge fly ash, malodors, or toxic substances.

Subpart D--Recognition of Facilities

Sec. 159.201 Recognition of facilities.

A recognized facility is an independent laboratory accepted by the Coast Guard under 46 CFR 159.010 to perform the tests and inspections required under this part. A list of accepted laboratories is available from the Commandant (G-MSE-3).

[CGD 95-028, 62 FR 51194, Sept. 30, 1997, as amended by USCG-1999-5832, 64 FR 34715, June 29, 1999]